AGN Winds on the Georgia Coast
Jekyll Island 2017

June 25-29th, 2017

Sponsored by:

Georgia State University

Scientific Program

Monday, June 26

7:30 am – 8:30 am Breakfast buffet, Check-in Morgan Center

8:30 am – 8:50 am Welcome and Introduction Morgan Center

8:50 am – 9:50 am Session 1: X-ray Absorbers and Ultra-Fast Outflows
(Chair: Mike Eracleous)

8:50 Jane Turner Mapping AGN Winds with X-ray reverberation
9:10 Misaki Mizumoto X-ray short time lags in the Fe-K band produced by disk winds in AGN
9:30 Sibasish Laha A comprehensive sample study of ionized absorbers in X-rays (WAX) in AGN. An insight into feedback and dynamics.

9:50 am – 10:20 am Coffee, posters

10:20 am – noon Session 1 (continued)
(Chair: Mike Eracleous)

10:20 Jerry Kriss Chasing obscuring outflows in AGN: Broad, Fast, UV and X-ray Absorption in NGC 3783 and other AGN
10:40 Tek P. Adhikari Absorption measure distribution in active galactic nuclei
11:00 George Chartas Quasar Outflows Near the Peak of AGN Activity.
11:20 Junjie Mao Self-consistent photoionized plasma modelling of NGC 3783 in X-rays
11:40 Smita Mathur Relics of AGN feedback in our Milky Way

Noon – 1:30 pm Lunch buffet, posters Club Ballroom

1:30 pm – 3:00 pm Session 1 (continued)
(Chair: Martin Elvis)

1:30 Daniel Proga The physical models and observational consequences of AGN winds
1:50 Chris Done Physical models for winds in AGN
2:10 Sergei Dyda Observational Features of X-ray Irradiated Flows
2:30 Yanfei Jiang Continuum Radiation Driven Outflow from Quasar Accretion
2:50 Anjali Gupta AGN Outflows: Probing an Unexplored Parameter Space

3:10 pm – 3:40 pm Coffee, posters

3:40 pm – 5:00 pm Session 1 (continued)
(Chair: Martin Elvis)

3:40 Steve Kraemer Probing the Physical Properties and Origins of Ultra-fast Outflows in AGN
4:00 Mariko Nomura A Novel Model for Line-driven Disk Winds: Origin of UFOs and Self-regulation of SMBH Growth
4:20 Keigo Fukumura A Magnetic View of AGN Disk-Winds
4:40 Massimo Gaspari Unifying the micro and macro properties of AGN feedback and feeding

5:00 pm – 6:00 pm Posters Morgan Center

Tuesday, June 27

7:30 am – 8:30 am **Breakfast Buffet** **Morgan Center**

8:30 am – 9:50 am **Session 2: Broad and Narrow Absorption Lines**
(Chair: Jane Turner)

8:30 Frederick Hamann On the Masses and Mass Loss Rates in Broad Absorption Line Outflows
8:50 Nahum Arav 50% of quasar outflows are situated at least 100 parsecs from the central source
9:10 Paola Rodriguez Hidalgo Emergence, Extremely High Velocities, and Strange Variability of Quasar Outflows
9:30 W. Niel Brandt Latest Results from a Large-Scale Spectroscopic Survey of Quasar Wind Variability

9:50 am – 10:20 am **Coffee, posters**

10:20 am – noon **Session 2 (continued)**
(Chair: Jane Turner)

10:20 Karen Leighly SimBAL: Spectral Synthesis for Broad Absorption Line Quasars
10:40 Patrick Hall Updates on Emergent and Redshifted BAL Quasars
11:00 James Matthews Testing quasar unification with radiative transfer simulations and large observational datasets
11:20 Kouichi Hagino Connection between UV and X-ray disk winds in APM 08279+5255
11:40 Chris Culliton Probing Quasar Winds Using Intrinsic Narrow Absorption Lines

Noon – 1:30 pm **Lunch buffet, posters** **Club Ballroom**

1:30 pm – 6:00 pm **Free afternoon, posters**

Wednesday, June 27

7:30 am – 8:30 am Breakfast Buffet Morgan Center

8:30 am – 9:50 am Session 3: Broad-Line Region, Torus, and Disk Winds
(Chair: Karen Leighly)

8:30 Martin Elvis A Cool Mist in a Warm Wind: the Origin of the Broad Emission Line Region
8:50 Sam Mangham Self-Consistent Reverberation Mapping of Emission Lines Formed in Rotating Disk Winds
9:10 Gordon Richards These aren't the BALs you're looking for (and other short stories)
9:30 Ari Laor On the source of the BLR Gas, and the Origin of the BAL Outflows

9:50 am – 10:20 am Coffee, posters

10:20 am – noon Session 3 (continued)
(Chair: Karen Leighly)

10:20 Peter Williams Modeling the broad line region of AGN with reverberation mapping data
10:40 Tim Waters Properties, dynamics, and spectral signatures of clouds in AGN
11:00 David Williamson What drives dusty winds? Radiation hydrodynamics of the parsec-scale environment of AGN
11:20 Sebastian Hoenig Dusty disks and dusty winds: How IR interferometry reshapes our picture of the circumnuclear environment of AGN
11:40 Peter Maksym Multi-wavelength Imaging of Sub-kpc Feedback in NGC 3393

Noon – 1:30 pm Lunch buffet, posters Club Ballroom

1:30 pm – 3:00 pm Session 4: Narrow-Line Region Outflows
(Chair: Fred Hamann)

1:30 Mike Crenshaw Outflows, inflows, and rotation in the Narrow-Line Regions of Seyfert Galaxies
1:50 Crystal L Gnilka Determining the Narrow-Line Region Geometry of Mrk 3 with Gemini/NIFS
2:10 Mitchell Revalski A Spatially Resolved Mass Outflow Rate for Markarian 573: In-Situ Radiative Driving of the Narrow Line Region Gas
2:30 Travis Fischer Do QSO2s have Narrow-Line Region Outflows? Implications for quasar-mode feedback
2:50 Daniel R. Dutra Ionized gas kinematics in local active galaxies: A comprehensive view of inflows and outflows

3:10 pm – 3:40 pm Coffee, posters

3:40 pm – 5:00 pm Session 4 (continued)
(Chair: Fred Hamann)

3:40 Taro Shimizu The Inner Regions of AGN: A SINFONI Study of Gas Outflows and Feeding in Local, X-ray Selected AGN
4:00 Francisco Muller-Sanchez The Keck OSIRIS Nearby AGN Survey: The Role of AGN-driven Outflows in the Evolution of Seyfert Galaxies
4:20 Xin Liu A high fraction of double-peaked narrow emission lines in powerful AGN
4:40 Rebecca Nevin Moderate Luminosity AGN as Drivers of Feedback

5:00 pm – 6:00 pm Posters Morgan Center

Thursday, June 29

7:30 am – 8:30 am Breakfast Buffet Morgan Center

(Chair: Daniel Proga)

8:30 am – 9:50 am Session 5: Galactic-Scale Outflows, Feedback

8:30 David Rupke Ubiquitous, Spatially Resolved Quasar-Mode Feedback in Nearby Quasars and Correlations with Black Hole Properties
8:50 Alex Richings Molecule formation in AGN-driven galactic winds
9:10 Laura Di Gesu The case of the galactic wind in 1H 0419-577
9:30 Guilherme S. Couto Circumnuclear gaseous kinematics and excitation of four local radio galaxies

9:50 am – 10:20 am Coffee, posters

10:20 am – noon Session 5 (continued)

(Chair: Daniel Proga)

10:20 Eckhard Sturm Molecular Outflows and Feedback in the Local Universe
10:40 Helen Russell Massive molecular gas flows and AGN feedback in galaxy clusters
11:00 Dong Zhang Radiation Hydrodynamics of Dust-Driven Galactic Winds
11:20 Rahul Kannan Increasing the coupling efficiency between the AGN driven winds and ICM through anisotropic thermal conduction
11:40 Michael Tremmel How to Quench a Galaxy

Noon – 1:30 pm Lunch buffet, posters Club Ballroom

1:30 pm – Conference Conclusion

Day One: Monday, June 26th

Session I: X-Ray Absorbers and Ultra-Fast Outflows

Chair: Mike Eracleous

Mapping AGN Winds with X-ray Reverberation

Jane Turner: The University of Maryland, Baltimore County

Joint consideration of X-ray timing data in conjunction with time resolved spectroscopy allows us to detect and interpret lags within the X-ray band and elucidate the origin of the time lags between different X-ray bands. The lags offer a chance to constrain the distance, global covering, physical state, velocity and mass of the X-ray reprocessing gas.

Notes:

X-ray short-time lags in the Fe-K band produced by disk winds in the active galactic nuclei

Misaki Mizumoto: JAXA/ISAS

In the X-ray energy band, short-time Fe-K lag features have been commonly observed in active galactic nuclei (AGNs). Many AGNs are known to have distant clouds or disk winds far from the central black holes, which can scatter primary X-ray photons and produce reverberation lags. Here, we performed Monte-Carlo simulations to calculate lag features produced by the distant clouds. As a result, we have found that the shorter (~100s) Fe-K reverberation lags than the light-travel time (~5000s) by one order of magnitude are produced, which suggests that the disk winds can reproduce the observed X-ray short-time lags.

Notes:

A comprehensive sample study of ionized absorbers in X-rays (WAX) in active galactic nuclei. An insight into feedback and dynamics

Sibasish Laha: University of California, San Diego

The last couple of decades have seen the most crucial developments in the understanding of AGN winds. This can be attributed mostly to the advent of great observatories like ALMA (Molecular outflows), Hubble space Telescope (UV outflows), XMM-Newton and Chandra (X-ray outflows). Coupled with advancement in theories, our understanding about AGN outflows in different wavelength bands (Radio, Infra-red, Optical, UV and X-rays) has never been better, yet there are many outstanding questions which we still need to answer. We present here the results from a comprehensive study of the warm absorbers (WA) in X-ray in a flux limited complete sample of Seyfert galaxies (WAX-I, Laha et. al. 2014, MNRAS 441, 2613), using high resolution XMM-Newton data. We found that the WA clouds are present in 65% of the sources. We also found a gap in the ionization parameter distribution of the WA, pointing to thermal instability. We have found evidences of WA being radiatively driven and they originate from the dusty torus (WAX-II, Laha et al. 2016, MNRAS 457, 3896L). The dust opacity can also play a leading role in driving these clouds. These WA clouds can sometimes give "effective feedback" to the host galaxies. In another extensive sample study of AGN exhibiting molecular outflows (to be submitted), we find that the AGN plays the most important role in driving these large kpc scale outflows. However, we are still uncertain how the AGN interacts with these large scale molecular clouds. We will also discuss the X-ray properties of the AGN exhibiting molecular outflows.

Notes:

Chasing obscuring outflows in AGN: Broad, Fast, UV and X-ray Absorption in NGC 3783 and other AGN

Jerry Kriss: STScI

Recent intensive multi-wavelength monitoring campaigns on bright, local active galactic nuclei have revealed a new class of UV and X-ray absorbers. They typically show transient, heavy X-ray obscuration in the low-energy spectrum characterized by high column densities of mildly ionized gas. These X-ray obscuration events are accompanied by the appearance of broad, fast, blue-shifted UV absorption lines of moderate ionization, comparable to the X-ray absorbing gas. X-ray column densities typically exceed 10^{22} cm^{-2} and UV absorption in Ly alpha, N V, Si IV, and C IV show blue shifts of 1000-8000 km/s and widths of 500-2000 km/s. The most prominent of these newly discovered outflows is in NGC 5548, but other examples have also been found in Mrk 335 and NGC 985. Here we report HST observations of broad, fast, UV absorption lines accompanying another case of obscuration in the Seyfert 1 galaxy NGC 3783. The high outflow velocities, variability timescales of a day or less in the X-ray, and the broad widths suggest an origin in a wind from the accretion disk. This low-ionization gas may represent the shielding gas necessary to facilitate disk winds driven by radiative acceleration in UV absorption lines.

Notes:

Absorption measure distribution in active galactic nuclei

Tek Prasad Adhikari: Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences

For the past decade, with the availability of high resolution X-ray spectra, outflows in active galactic nuclei (AGN) have been studied with great details. The most common observed feature of these outflows in several sources is their broad ionisation distribution spanning ~ 4 orders of magnitude in ionization levels. This feature is quantified in terms of absorption measure distribution (AMD), defined as the distribution of column density with ionisation parameter. In this work, we present the AMD models for 7 sources derived from the photoionisation modeling of an ionised plasma in the outflow of AGN using the numerical code **TITAN** and compare them with the currently available AMD shapes constructed from X-ray spectra of these objects. We demonstrate that, the shape of the observed AMD can be reproduced by assuming that the warm absorber is a single zone of ionised gas cloud under constant total pressure i.e., $P_{rad}+P_{gas}$ = constant. We show that the observed discontinuities in AMD can be well described by the eventual thermal instability caused by strong gas irradiation.

Notes:

Quasar Outflows Near the Peak of AGN Activity

George Chartas: College of Charleston

We present results from the analysis of the X-ray spectra of a sample of intrinsic-NAL, BAL and mini-BAL quasars that show significantly blueshifted and highly ionized absorption lines. We interpret these blueshifted absorption lines as the result of near relativistic outflows and provide constraints on the wind properties. Specifically, we constrain the outflow velocities, ionization parameters, absorbing column density, launching radii, mass-outflow rates, momentum rate change and efficiency of the outflows. These quantities are important in assessing the contribution of these winds to a feedback process that is thought to regulate the growth of their host galaxies. The outflow properties provide an insight to the dominant driving mechanism of the winds. We finally present the results of our correlation analysis between the properties of the quasar winds and the bolometric luminosities of the high redshift quasars in our sample. Our correlation results are compared to earlier studies performed on nearby Seyfert galaxies.

Notes:

Self-consistent photoionized plasma modelling of NGC 3783 in X-ray

Junjie Mao: SRON Netherlands Institute for Space Research

In 2016, a Swift monitoring was carried out to track the X-ray hardness variability of eight Seyfert 1 galaxies, aiming at catching intense X-ray spectral hardening events caused by obscuration. For NGC 3783, a heavily obscured state of the source in the X-ray band, as well as broad absorption lines in the UV band, was caught in December 2016 and thereby triggered joint XMM-Newton, HST and NuSTAR observations. A similar obscured state has been observed before in NGC 5548, another Seyfert 1 galaxy. For NGC 3783, this is the first X-ray grating observation of this heavily obscured state. We analyze both archival (unobscured) and new (obscured) grating spectra from Chandra and XMM-Newton, with a total exposure of 1.4 Ms. The self-consistent photoionized plasma model (PION) in the SPEX code is used to fit both absorption and emission features in the spectra. The absorption features are caused by the warm absorber, and the newly discovered obscuring wind from the new data. The obscuring wind is found to be variable on timescales of days, with both its covering fraction and column density changing. The emission features, including both narrow emission lines and radiative recombination edges of C, N, O and Ne, are clearly visible in the new data due to the heavy absorption of the continuum. We successfully model the main emission features with two PION components. We discuss different physical properties of the obscuring wind, warm absorber and emitter around the central engine.

Notes:

Relics of AGN feedback in our Milky Way

Smita Mathur: The Ohio State University

We have been studying the physical properties as well as mass content of hot baryons in our Galaxy. An important step in this regard is to determine the density distribution of the gas and our work led to a surprising discovery. We found that a vast, 6 kpc radius, spherically-symmetric central region of the Milky Way above and below the thick plane, has either been emptied of hot gas or the density of this gas within the cavity has a peculiar profile, increasing from the center up to a radius of 6 kpc, and then decreasing with a typical halo density profile. This evidence suggest that the current surface of the cavity, at 6 kpc from the Galaxy's center, traces the distant echo of a period of strong nuclear activity of our super-massive black-hole that occurred about 6 Myrs ago. Interestingly, the nuclear cavity shows resemblance to the Fermi bubbles, the most spectacular structures observed at the Galactic center.

Notes:

The physical models and observational consequences of AGN winds

Daniel Proga: University of Nevada Las Vegas

I review the physics of launching and acceleration of AGN winds. I will consider two kinds of outflows powered by radiation emitted from the AGN central engine: 1) disk winds and 2) outflows driven from a large-scale inflow. I discuss the relevance of both types of outflows to the so-called AGN feedback problem. However, as the AGN feedback should not be considered separately from the inner working of AGN, I also discuss the issue whether the properties of the same outflows are consistent with the observed gas properties in broad- and narrow-line regions of AGN.

Notes:

Physical models for winds in AGN

Chris Done: Durham University

We observe many types of winds in AGN, seen most obviously as blue shifted absorption lines in the X-ray and UV bandpasses. These are termed warm absorbers and ultrafast outflows in X-rays, and broad and narrow absorption lines in the UV. There are also multiple different physical mechanisms for wind formation, super-Eddington sources should power strong winds from the inner disc, UV line driving can power winds from sub-Eddington discs if they are UV bright and X-ray weak, then dust driving and thermal expansion can drive winds from material further out from the disc and magnetic fields can do anything. I will discuss how each wind depends on the mass and mass accretion rate of the black hole, and put together a structure for the accretion flow as a function of these physical parameters, with input from the new intensive multi wavelength reverberation mapping campaigns on NGC5548 and other objects.

Notes:

Observational Features of X-ray Irradiated Flows

Sergei Dyda: UNLV

Confronting observations of AGN winds with predictions from the theory of outflows have not led to a clear understanding of the relative roles of the three candidate driving mechanisms: thermal, radiation, and magnetic driving. We develop a general method for the self-consistent calculation of the hydrodynamics of an astrophysical object irradiated by a radiation field with an arbitrary strength and spectral energy distribution (SED). This consists of 1) using the XSTAR photoionization code to calculate heating and cooling rates for a given SED as a function of gas photoionization parameter and temperature and 2) Using the Athena++ MHD code to study the resulting hydrodynamic flows.

Notes:

Continuum Radiation Driven Outflow from Quasar Accretion Disks

Yanfei Jiang: KITP, University of California, Santa Barbara

Accretion disks around supermassive black holes have regions where the Rosseland mean opacity can be larger than the electron scattering opacity due to the large number of bound-bound transitions in iron as well as the ionization of hydrogen. Therefore, although the bolometric luminosity can be sub-Eddington for electron scattering opacity, local radiation accretion can be much larger than the gravitational accretion due to these opacity peaks. I will show the first global 3D radiation MHD simulation to study the structures of quasar accretion disks with sub-Eddington accretion rate as well as the radiation driven outflow from the inner regions of the accretion disks. When the accretion rate is above the Eddington limit as during the growth of black holes in the early universe, strong radiation driven outflow is also unavoidable. I will show simulations in this regime and compare the properties of the radiation driven outflow with different accretion rates. I will also discuss implications of these simulations for the observations of radiation driven outflow from quasars.

Notes:

AGN Outflows: Probing an Unexplored Parameter Space

Anjali Gupta: Columbus State Community College

We recently discovered relativistic outflows in high-resolution grating spectra in the soft X-ray band with multiple absorption lines of multiple elements. These detections are robust and alleviate earlier concerns about statistical significance of lines in CCD spectra in the hard X-ray band. This opens up an exciting new possibility of in depth study of relativistic outflows. I will discuss the our recent results on the discovery of high velocity outflows in the narrow line Seyfert 1 galaxies Ark 564 and Mrk 590. These absorbers are identified through multiple absorption lines at blueshifts of 0.1c-0.17c detected in the Chandra HETG-MEG spectra. The high-velocity outflows detected in the soft X-ray band have low-column, and low-ionization parameter, thus probing a distinct region in the parameter space (ionization, column density, velocity). The presence of such relativistic outflows in Seyfert galaxies poses a challenge to theoretical models of AGN winds. I will briefly discuss existing models and future prospects.

Notes:

Probing the Physical Properties and Origins of Ultra-fast Outflows in AGN

Steve Kraemer: Catholic University of America

Approximately half of Type 1 AGN possess intrinsic absorption and high resolution UV and X-ray spectroscopy have revealed that the absorbing gas is radially outflowing, with velocities of 100s to 1000s km/sec. X-ray ("warm") absorbers, originally revealed by the presence of bound-free edges of O VII and O VIII, are more highly ionized than their UV counterparts, and, photo-ionization modeling studies have determined that they have ionization parameters of log(U) ~ -1 to 1. Recently, XMM-Newton spectra have detected much more highly ionized gas, with log(U) > 2, producing absorption lines from H- and He-like Fe. Some of these absorbers, "Ultra Fast Outflows (UFOs)", have radial velocities up to 0.2c. We have undertaken a detailed photo-ionization study of high-ionization Fe absorbers, both UFOs and non-UFOs, in a sample of AGN observed by XMM-Newton. We find that the UFOs are completely Compton-cooled, unlike the non-UFOS. Both types are too highly ionized to be radiatively accelerated, hence they are more likely driven via Magneto-Hydrodynamic processes. Their large column densities and velocity gradients are consistent with flows along magnetic streamlines emanating from accretion disks. Open questions include: the temporal stability of the UFOs, the apparent lack of non-UFOs in UFO sources, and their relationship to warm absorbers.

Notes:

A Novel Model for Line-driven Disk Winds: Origin of UFOs and Self-regulation of SMBH Growth

Mariko Nomura: Keio University

We developed a novel model for line-driven disk winds, which successfully explains an origin of ultra-fast outflows (UFOs) in active galactic nuclei (AGNs) and self-regulation mechanisms for growth of supermassive black holes (SMBHs). By performing two-dimensional radiation hydrodynamics simulations considering the radiation force due to spectral lines, we found that the line-driven disk winds successfully explain the features of the UFOs, which are inferred from the observations of blueshifted absorption lines of highly ionized iron (Nomura et al. 2016, 2017). Our model reproduces the velocity, column density, and ionization state of the UFOs. In addition, our results explain the latest observations that the mass outflow rate, momentum flux, and kinetic luminosity of the UFOs are scaling with the AGN luminosity. Furthermore, we improve the simulations in order to calculate the mass accretion rate and the mass outflow rate due to the disk wind self-consistently. As a consequence, the mass outflow rate increases as the mass inflow rate at the outer edge of the accretion disk approaches the Eddington accretion rate. When the inflow rate is 90% of the Eddington accretion rate, about a half of the inflowing mass are ejected from the disk as the disk wind and the other half accrete onto the SMBH. These results show that the line-driven disk winds suppress the accretion rate onto SMBHs and prevent overgrowth of SMBHs in the final stage of their evolution. Our results are consistent with the observational fact that most quasars are sub-Eddington.

Notes:

A Magnetic View of AGN Disk-Winds

Keigo Fukumura: James Madison University

In addition to accretion processes in AGNs, the ubiquitous presence of a diverse population of outflows in AGNs has become more obvious. Despite an increasing number of observational evidences in AGN X-ray data over the past decades, however, the physical identity of the detected blueshifted X-ray absorbers remains elusive to date with an ambiguous speculation of its geometrical structure and launching mechanism. With reliable spectral identification for some bright AGNs, on the other hand, one can reconstruct the absorption measure distribution (AMD) for various ions of different charge states, which in turn tells us the broad distribution of the observed line-of-sight columns over many decades in ionization parameter. With such a tool in hands, we have been modeling a number of AGN X-ray absorbers, both the stereotypical warm absorbers (WAs) and the ultra-fast outflows (UFOs), in the context of magnetically-driven disk-winds. The primary goal of this study is to fully exploit theoretical implications of such magnetic-winds for both individual spectral features (e.g. Fe at ~1A to Ne at ~10A) and its large-scale wind condition. As a case study, we will present our recent analyses for PG 1211+143 and NGC 3783 also in comparison with the well-known disk-winds seen in XRBs such as GRO J1655-40 to demonstrate a fundamental characteristics of magnetic-winds across the different mass scale.

Notes:

Unifying the micro and macro properties of AGN feedback and feeding

Massimo Gaspari: Princeton University

I highlight recent advancements in the theoretical and numerical modeling of self-regulated AGN feedback, as linking for the first time the large-scale and horizon kinetic efficiencies of SMBHs. High-resolution 3D hydro simulations show the turbulent X-ray halo radiatively cools through a top-down multiphase condensation cascade of extended warm filaments and molecular clouds, in agreement with Chandra, SOAR, Herschel, and ALMA data. In the nuclear region, the condensed structures collide in inelastic way, mixing angular momentum and leading to chaotic cold accretion (CCA). The CCA fluctuations are key to explain the ubiquitous rapid variability of AGN. Within 100 gravitational radii - probed by GR-MHD simulations - the accretion energy is transformed into ultrafast 10000 km/s outflows which eject most of the inflowing mass. At kpc scales, the energy-driven outflow slows down entraining progressively more mass and generating the commonly observed ionized, neutral, and molecular macro AGN outflows. At larger scales, the AGN mechanical energy thermalizes via bubbles, shocks, and turbulence, preserving the hot halos of galaxies and galaxy clusters in quasi thermal equilibrium throughout their Gyr evolution.

Notes:

Day Two: Tuesday, June 27th

Session II: Broad and Narrow Absorption Lines

Chair: Jane Turner

On the Masses and Mass Loss Rates in Broad Absorption Line Outflows

Frederick Hamann: University of California, Riverside

Quasar outflows are fundamental components of quasar environments and they might play an important role in feedback to host galaxy evolution. We are studying broad absorption line (BAL) and "mini-BAL" outflows with resolved narrow lines that provide strong constraints on the densities, column densities, and locations and, ultimately, the mass loss rates and energetics of these flows. These rare line-rich outflow systems might provide valuable insights into the general phenomenon of quasar accretion-disk outflows. In one case, the quasar PG1411+442 (redshift = 0.089), we obtained HST-COS spectra that revealed a low-velocity (~1900 km/s) but very high column density mini-BAL outflow with rare features like PV 1118,1128 and CIII* 1175, SiII/SiII, etc., in addition to the usual CIV and NV high-ionization lines. Subsequent HST-COS observations showed the remarkable emergence of a unique new transient outflow that produces (at least) hundreds of weak and narrow (FWHM ~ 100-150 km/s) absorption lines across rest-frame UV at the same velocity as the mini-BAL outflow. These lines in the transient include many FeII* transitions from excited states up to 3.9eV, unusual lines of NiII*, OI*, CI*, and NI*, plus NaI D, the HI* Balmer lines and a unique detection of HeI* 5875 in the visible. These features identify very high densities (n_H > 10^8 cm^{-3}, possibly > 10^9 cm^{-3}) and enormous column densities ($N_H > 10^{23}$ cm^{-2}) in small outflow clumps or streams that cover just ~ 20% of the quasar continuum source. Continued monitoring shows further changes that we attribute to outflow structures crossing our lines of sight at high speeds (> 1000 km/s) close to the central black hole. The location and derived physical conditions are similar to broad-emission line clouds, suggesting that the transient absorber might be a fragment of the broad emission-line region that wandered into our line of sight.

Notes:

50% of quasar outflows are situated at least 100 parsecs from the central source

Nahum Arav: Virginia Tech

The most robust way for determining the distance of quasar absorption outflows is the use of troughs from excited states. Here we report the results of two surveys targeting outflows that show troughs from S IV. One survey includes 1091 SDSS and BOSS quasar spectra, and the other includes much higher quality spectra of 13 quasar observed with the Very Large Telescope. We demonstrate that the depth ratio of S IV* to S IV troughs is a powerful diagnostic for the distance of the outflows from the central source. Since S IV is formed in the same physical region of the outflow as the canonical outflow-identifying species C IV, the results of these surveys are applicable to the large majority of quasar outflows. We find that at least 50% of quasar outflows are at distances larger than 100 parsecs from the central source, and at least 12% are at distances larger than 1000 parsecs. These results have profound implications to the study of the origin and acceleration mechanism of quasar outflows, and their effects on the host galaxy.

Notes:

Emergence, Extremely High Velocities, and Strange Variability of Quasar Outflows

Paola Rodriguez Hidalgo: Humboldt State University

We will present the results of a study of appearance of new broad absorption lines (BALs) in quasar spectra that our group has carried out by using spectroscopic data from the Sloan Digital Sky Survey (SDSS) legacy dataset (SDSS-I/II) and the Baryon Oscillation Spectroscopic Survey (BOSS) SDSS-III. We compare quasar spectra with sufficient signal-to-noise and large enough redshift to search for the emergence of CIV 1550 absorption in quasars where the absorption was not previously present, and determine the rate of emergent outflows in quasar spectra. We will discuss how this rate compares to the rate of disappearance of quasars already in the literature, and share a database of extremely high velocity outflows ($v > 30{,}000$ km/s) for follow-up studies. We will also present the interesting case of LBQS 0051-0019, one of the quasars discovered in the above analysis, where the absorption returned to a previously observed depth in follow-up observations, 3.7 years later in the rest-frame. We will discuss the possible causes for this particular variability in the context of orientation of the outflows relative to the central AGN.

Notes:

Latest Results from a Large-Scale Spectroscopic Survey of Quasar Wind Variability

W. Niel Brandt: Penn State Astronomy & Astrophysics

I will present the latest results from our large-scale, and still growing, spectroscopic survey of multi-year ultraviolet broad absorption line (BAL) variability in ~ 2100 luminous quasars. This survey is primarily based on spectra from the ongoing Sloan Digital Sky Survey (SDSS-I through SDSS-IV TDSS) and is about two orders of magnitude larger than past comparable surveys - it is helping to transform the field of multi-year BAL variability studies into one that supplies robust statistical constraints that can effectively guide models of quasar winds and their feedback. Additional multiwavelength observations, especially in the X-ray band, have been obtained to complement the SDSS spectra when important. I will highlight novel results from this project on, e.g., disappearing and emerging BALs, BAL acceleration/deceleration, coordinated variations of multiple C IV troughs, rapid BAL variability, variations of extreme BALs, BAL vs. emission-line variability, unusually stable BALs, and redshifted BAL profile variability. I will end by discussing future prospects for large-sample BAL variability studies and open questions needing further investigations.

Notes:

SimBAL: Spectral Synthesis for Broad Absorption Line Quasars

Karen Leighly: The University of Oklahoma

Despite years of study, physical constraints on broad absorption line quasar outflows have been obtained from only a handful of objects. We introduce SimBAL, a spectral synthesis fitting method for BALQSOs, which compares synthetic spectra computed from photoionization model results with observed spectra using Bayesian model calibration. We demonstrate its application on a range of BAL phenotypes, and discuss our results and future prospects.

Notes:

Updates on Emergent and Redshifted BAL Quasars

Patrick Hall: York University

We report on Gemini+GMOS follow-up of two BAL quasar subgroups. First, we have studied 105 quasars with C IV BAL troughs which emerged between SDSS and BOSS spectral epochs. The emergence rate is consistent with the previously reported BAL trough disappearance rate. There is strong coordinated variability among troughs in the same quasar, likely due to gas at different velocities responding to the same ionizing flux changes. The coordination is stronger if the velocity separation between the troughs is smaller. This effect may be due to clouds having on average lower densities at higher velocities due to mass conservation in an accelerating flow, causing the clouds to respond on different timescales to the same ionizing flux variations. Second, we have obtained new optical and near-IR spectra and X-ray observations of BAL quasars with troughs which are redshifted relative to the quasar rest frame, by up to 14,000 km/s. Possible explanations for gas at these velocities put forward in our discovery paper included binary quasars, rotationally dominated outflows, and gas infall reaching relatively small radii from the black hole. The detection of X-ray absorption in these objects, their spectral variability properties, and comparison of their absorption profiles to predictions for simple parabolic and radial infall models leads us to conclude that rotationally dominated outflows are the favored explanation.

Notes:

Testing quasar unification with radiative transfer simulations and large observational datasets

James Matthews: University of Oxford

Arguably the most spectacular evidence of outflows in AGN is provided by the broad absorption lines (BALs) seen in approximately 20% of quasars. The incidence of BAL quasars is often interpreted in a geometric sense, in which the covering factor of the outflow roughly corresponds to the BAL fraction; such a model offers a natural way to unify much of the diverse phenomenology of quasars, particularly if the outflow itself can produce broad emission lines (BELs). Here, I present tests of this paradigm. I first discuss fully self-consistent radiative transfer and photoionization calculations using a simple prescription for an equatorial, clumpy, biconical disc wind. I demonstrate that the wind produces BALs at high inclinations and BELs at low inclinations, while displaying the full range of ionization states observed in the BLR. However, a subsequent investigation of emission line properties of quasars using the SDSS reveals that the equivalent width distributions of BAL and non-BAL quasars are remarkably similar, a property that suggests either BAL quasars are seen from low to intermediate inclinations, or that the UV-optical continuum in quasars does not emit like an optically thick disc. I review these results in the context of other orientation indicators, before exploring how alternative (non-equatorial) geometries may provide the first successful wind-based unification model to be subjected to full 2.5D radiative transfer and photoionization calculations. Whilst there are clearly a number of challenges for the simplest flavour of disc wind unification models, they nonetheless remain promising, particularly as they naturally reproduce many of the observed BLR and absorption properties.

Notes:

Connection between UV and X-ray disk winds in APM 08279+5255

Kouichi Hagino: ISAS/JAXA

Active galactic nuclei often show blue shifted absorption lines in their UV or X-ray spectra, indicating existence of powerful disk winds. X-ray winds called UFOs (Ultra-Fast Outflows) and UV winds called BALs (Broad Absorption Lines) are the most powerful subclasses of disk winds with velocities of ~0.1-0.3c in UFOs and ~0.01-0.1c in BALs. Since a large amount of kinetic energies are expected to be transported to their host galaxies, these powerful disk winds are widely believed to play a significant role in coevolution of supermassive black holes and galaxies. However, relation between these two types of disk winds is not clear because most of UFO sources do not show any BAL features. A luminous BAL quasar APM 08279+5255 is a rare source showing both BAL and UFO. Thus, in order to study the physical properties of the UFOs in a BAL quasar, we analyze all the available X-ray data of this source obtained with Chandra, XMM-Newton and Suzaku with our spectral model of highly ionized disk winds constructed by 3D Monte Carlo radiation transfer simulation, which was already applied to the typical UFO source PDS 456, and successfully reproduces all the observed spectra. As a result, we find a systematic decrease of the outflow velocity of the X-ray disk wind from ~0.2c to ~0.1c in a time scale of 6-8 years, which is correlated with the decrease of absorption line equivalent width. Interestingly, the BAL in this source also shows a similar decrease of the equivalent width in the same period from 2001 to 2008. We show possible correlation between UFO and BAL and discuss its physical origin.

Notes:

Probing Quasar Winds Using Intrinsic Narrow Absorption Lines

Chris Culliton: Penn State University

We use the spectra of 73 quasars ($1.5 < z < 5$) from the VLT UVES archive to catalog and study narrow absorption lines (NALs) that are physically associated with (intrinsic to) the quasars. Our aim is to better understand the characteristics of the gas producing the NALs and its relation to the quasar central engine. We identify 412 NAL systems containing C IV, N V, and/or Si IV doublets. Based on the assumption that only systems intrinsic to the quasar can exhibit partial coverage of the background source(s), we identify 33 reliably intrinsic NAL systems, and 11 systems that are potentially intrinsic, as well as 4 mini-BALs and 1 BAL. The minimum fraction of quasars with at least one intrinsic NAL system is found to be 38%. We identify intrinsic NALs with a wide range of properties, including ejection velocity, coverage fraction, ionization level, and preferred host quasar type. We find that there is a continuum of properties within the intrinsic NAL sample, rather than discrete families, ranging from partially covered C IV systems with black Lya and with a separate low ionization gas phase to partially covered N V systems with partially covered Lya and without detected low ionization gas. Additionally, we construct a model describing the spatial distributions, geometries, and varied ionization structures of intrinsic NALs. Within the context of this model, the higher ionization systems tend to be closer to the source of ionizing radiation.

Notes:

Day Three: Wednesday, June 28th

Session III: Broad-Line Region, Torus, and Disk Winds

Chair: Karen Leighly

A Cool Mist in a Warm Wind: the Origin of the Broad Emission Line Region

Martin Elvis: Harvard-Smithsonian Center for Astrophysics

The origin of the broad emission line region (BELR) in quasars and active galactic nuclei is still unclear. I propose that a mist of cool condensations forms in the warm, radiation pressure driven, accretion disk wind of quasars creating the BEL clouds and uniting them with the other two manifestations of cool (~10^4 K) gas in quasars, the low ionization phase of the warm absorbers (WAs) and the clouds causing X-ray eclipses. The cool clouds will condense quickly (days - years), before the WA outflows reach escape velocity (which takes months - centuries). Cool clouds form in equilibrium with the warm phase of the wind because the rapidly varying X-ray quasar continuum changes the force multiplier, causing pressure waves to move gas into stable locations in pressure-temperature space. The narrow range of 2-phase equilibrium densities may explain the luminosity$^{1/2}$ scaling of the BELR size, while the scaling of cloud formation timescales could produce the Baldwin effect. These dense clouds have force multipliers of order unity and so cannot be accelerated to escape velocity. They fall back on a dynamical timescale (months - centuries), producing an inflow that rains down toward the central black hole. As they soon move at Mach ~10 - 100 with respect to the WA outflow, these "raindrops" will be rapidly destroyed within months. This rain of clouds may produce the elliptical BELR orbits implied by velocity resolved reverberation mapping in some objects, and can explain the opening angle and destruction timescale of the narrow "cometary" tails of the clouds seen in X-ray eclipse observations. Some consequences and challenges of this "quasar rain" model are presented along with several avenues for theoretical investigation.

Notes:

Self-Consistent Reverberation Mapping of Emission Lines Formed in Rotating Disk Winds

Sam Mangham: University of Southampton

Disk winds are commonly invoked as an explanation for the broad-line region (BLR) of AGN. The emission lines produced in the BLR respond to changes in the ionising continuum with delays ranging from days to months. Associating these delays with light travel times then immediately provides an estimate of the size of the BLR. However, it is also possible to use carry out 2-D reverberation mapping, i.e. to estimate the line response to continuum variations as a function of both time-delay and velocity. The resulting response function (aka velocity-delay map) encodes key information about the geometry and kinematics of the BLR. Here, we use a Monte Carlo radiative transfer and ionisation code to predict the time- and velocity-resolved 2-D response functions for smooth (or "micro-clumped") rotating biconical disk wind models. Self-shielding, multiple scattering and the ionisation structure of the outflow are all self-consistently taken into account. We show that, in general, positive line responses are very similar to those produced by purely rotationally-dominated flows. However, we also find that disk winds can produce significantly negative responses across a range of velocities and delays. Attempts to invert observational data to recover response functions will need to explicitly allow for this possibility. On the other hand, such negative reverberation signature may provide a new way to distinguish rotating outflows from rotating disks.

Notes:

These aren't the BALs you're looking for (and other short stories)

Gordon Richards: Drexel University

I begin by emphasizing the diversity of quasar outflows, but stress that the adoption of the term "broad absorption line" quasar to refer to *all* outflows is causing chaos in the literature. Classical BALs, while perhaps not unique in having outflows, have properties that are very much worth exploring independently of other outflows. In that context, I will present the latest installment in my decade-long attempt to understand quasars outflows using emission lines rather than absorption lines, particularly highlighting preliminary results from Independent Component Analysis and recent success in disambiguating CIV black hole masses.

Notes:

On the source of the BLR Gas, and the Origin of the BAL Outflows

Ari Laor: Technion

The similar values of the radiation pressure incident on the BLR, and the pressure of the gas at BLR, suggest the gas is being compressed by the incident radiation pressure. This radiation pressure compression (RPC) may also provide a natural solution to the overionization problem for the BAL outflow. Furthermore, ablation of this gas inevitably produces a sheared outflowing surface layer, with an expected ionization and velocity structure similar to the one observed in BAL winds.

Notes:

Modeling the broad line region of AGN with reverberation mapping data

Peter Williams: University of California, Los Angeles

Traditional reverberation mapping uses the time lag between changes in the AGN ionizing continuum and the broad line response in order to measure a characteristic radius of the broad line region. This allows for a simple virial estimate of the black hole mass, up to a normalization factor of order unity, which accounts for the different possible shapes and kinematics of the broad line region. The normalization factor introduces the largest amount of uncertainty in black hole mass measurements, on the order of 0.4 dex. I will discuss a method that models the broad line region directly which reduces black hole mass measurement uncertainties to less than 0.3 dex as well and infers properties of broad line region structure and kinematics. I used this method to analyze reverberation mapping data from the Lick AGN Monitoring Project (LAMP) 2011. The results show at least two AGN with clear signs of outflowing gas. I will discuss how these objects can be used as a testbed for examining different outflow models in order to improve the model of the broad line region. This will allow for more precise black hole mass measurements and will help constrain the nature of outflows in AGN.

Notes:

Properties, dynamics, and spectral signatures of clouds in AGN

Tim Waters: University of Nevada Las Vegas

The notion of discrete clouds in AGN dates back to the earliest attempts to explain the observed broad and narrow emission and absorption lines. While the schematic picture of unified models features such clouds, the properties and dynamics of AGN clouds remain largely unconstrained. In recent papers we have critically assessed the plausibility of this picture by studying the nonlinear dynamics of the thermal instability, as this is a natural mechanism through which clouds can form. Under this scenario, we know the expected size distributions of clouds, their formation and disruption timescales, and their dynamics. Here we summarize our understanding and present synthetic spectra for how clouds would be perceived if they are evolving along our line of sight. Moreover, we speculate on whether the idea of a clumpy outflow can unify the classic cloud scenario and large-scale wind models.

Notes:

What drives dusty winds? Radiation hydrodynamics of the parsec-scale environment of AGN

David J Williamson: University of Southampton

With the discovery of dusty winds dominating the AGN infrared radiation on parsec scales, it has become clear that the classical idea of a circumnuclear dusty torus needs a make-over. Indeed, it has always been problematic to produce a physical framework to simultaneously explain all the properties of the dusty torus required by observations - geometric thickness, cool temperatures, and clumpiness. Simulations face the difficulty of resolving sub-parsec clumping simultaneously with accounting for the larger scale dust distribution. We are building a new 3D radiative hydrodynamical model to obtain a realistic physical picture of the parsec scale environment. The new simulations include self-gravity effects as well as radiation pressure from the central source and the accreted medium, with the goal of explaining the observed dusty wind features together with obscuring and emission properties. In this talk, we will present the first results from the new RHD simulations. We will identify which components of our physical model are required to generate a thick torus with a dusty wind, and how each of these components contribute to producing the observed properties. We will also discuss how the simulated winds relate to the accretion state of the AGN and to the observed large-scale narrow line region.

Notes:

Dusty disks and dusty winds: How IR interferometry reshapes our picture of the circumnuclear environment of AGN

Sebastian Hoenig: University of Southampton

The classical "dusty torus" has long been held responsible for angle-dependent obscuration and as the origin of the infrared (IR) emission from AGN. Current models to interpret the IR emission are based on this torus paradigm. Using infrared interferometry, it was recently discovered that the bulk of the mid-IR emission is not originating from a compact torus, but from an extended source in the outflow region of the AGN, ranging from sub-parsec scales to hundreds of parsecs. A new paradigm is emerging where two components - a geometrically thin dusty disk and an extended dusty wind - are responsible for the observed IR emission, obscuration, and potentially feedback reactions. In this talk, I will review the current state of knowledge from resolved IR observations of AGN. New radiative transfer models are presented that are able to simultaneously reproduce the observed SEDs and geometric distribution of the light ("CAT3D-WIND"; Hönig & Kishimoto 2017, ApJL, 838, L20). I will discuss implications for AGN unification, possible wind driving mechanisms, and AGN feedback.

Notes:

Multi-wavelength Imaging of Sub-kpc Feedback in NGC 3393

Peter Maksym: Harvard-Smithsonian Center for Astrophysics

NGC 3393 is the nearest Compton-thick Swift BAT AGN to have both L_X (15-55 keV) > 10^{42} erg/s and a spatially-resolved sub-kpc radio outflow, and is therefore an exceptional laboratory for investigating AGN feedback. At only 53 Mpc, the angular scale is sufficient to spatially resolve the outflow and the surrounding NLR simultaneously with HST, Chandra and the VLA. Simultaneous contributions to the resolved NLR from the jet, AGN wind, and photoionization of spiral arm gas are evident. But spatial resolution is key to teasing out the different components of a multiphase NLR, where multiple feedback mechanisms would be confused when the nucleus is taken as a whole. We discuss multi-wavelength evidence for outflow-driven shocks enabled by high-resolution spatial discrimination from the photoionized NLR.

Notes:

Session IV: Narrow-Line Region Outflows

Chair: Fred Hamann

Outflows, inflows, and rotation in the Narrow-Line Regions of Seyfert Galaxies

Mike Crenshaw: Georgia State University

We present recent results on the kinematics of the narrow-line regions (NLRs) in nearby Seyfert galaxies based on observations with the Gemini Near Infrared Field Spectrometer (NIFS), obtained in the Z, J, and K bands at an angular resolution of ~0.1" and a spectral resolving power of ~5000. We find strong evidence for in situ radiative driving of ionized gas away from molecular gas/dust spirals that enter the AGN ionizing bicone within ~1 kpc of the supermassive black hole (SMBH). We also detect outflowing warm molecular (H_2) gas inside of ~1 kpc after subtraction of the stellar velocity field from the CO bandheads. Our long-slit spectra from the Apache Point Observatory 3.5-meter telescope show that the AGN-ionized gas is typically dominated by rotation beyond ~1 kpc from the central SMBH and often extends out to at least several kpc, defining the extended NLR (ENLR). The NLR outflows in these moderate-luminosity AGN may not be sufficient to evacuate their entire bulges.

Notes:

Determining the Narrow-Line Region Geometry of Mrk 3 with Gemini/NIFS

Crystal L Gnilka: Georgia State University

We present an in-depth mapping of the narrow-line region (NLR) of the Seyfert 2 galaxy Mrk 3, using observations from Gemini North's Near-infrared Integral Field Spectrometer (NIFS). The NLR of Mrk 3 is composed of several overlapping and spatially-defined emission-line knots that together form a characteristic backwards "S" shape. These knots exhibit both high-velocity (~1000 km/s) and medium-velocity (~400 km/s) emission that are most likely due to outflows originating primarily in dust/gas spirals in the galaxy's disk, which are being ionized by the AGN's ionizing bicone. We compare these kinematics and those from an extended region from Apache Point Observatory's (APO) 3.5m Dual-Imaging Spectrometer (DIS) with our previous work on Mrk 3 using the Hubble Space Telescope's (HST) Space Telescope Imaging Spectrograph (STIS), and present a new outflow model consistent with these additional observations.

Notes:

A Spatially Resolved Mass Outflow Rate for Markarian 573: In-Situ Radiative Driving of the Narrow Line Region Gas on Scales of Hundreds of Parsecs

Mitchell Revalski: Georgia State University

We present spatially resolved mass outflow rate measurements for the narrow line region (NLR) of the Seyfert 2 galaxy Markarian 573. Using long slit spectra and [O III] imaging from the *Hubble Space Telescope* and Apache Point Observatory in conjunction with Cloudy photoionization models we find a peak outflow rate of ~3 solar masses per year at a distance of 250 pc from the central supermassive black hole (SMBH). The outflow extends to ~600 pc, with additional evidence of gas ablating off spiral dust lanes in rotation at distances of ~750 pc. The peak outflow rate is approximately 8 times the mass accretion rate inferred from the bolometric luminosity, and 60 times the mass outflow rate calculated for the nucleus, indicating in-situ acceleration of the NLR gas. This result is similar to that reported by Crenshaw et al. 2015 for the lower luminosity Seyfert NGC 4151, but the outflow in Mrk 573 extends nearly 5 times further from the nucleus. These results indicate that NLR outflows may contribute significantly to active galactic nuclei (AGN) feedback in the inner bulge. We demonstrate here the methodology that we will apply to additional AGN with the goal of probing feedback and correlations between the strength of the outflow and properties of the AGN such as SMBH mass, bolometric luminosity, and Eddington ratio.

Notes:

Do QSO2s have Narrow-Line Region Outflows? Implications for quasar-mode feedback

Travis Fischer: NASA's Goddard Space Flight Center

We present a Hubble Space Telescope (HST) survey of extended [O III] emission for a sample of 11 nearby ($z < 0.12$), luminous Type 2 quasars (QSO2s) which we use to measure the extent and kinematics of their AGN-ionized gas. Recent studies of ionized-gas extent and kinematics in nearby Seyfert galaxies have shown that while ionized gas emission extends out to several kpcs, rotation kinematics dominate the majority of the gas. We find that outflowing gas extends to distances less than 1 kpc, suggesting that outflows in Seyfert galaxies may not be powerful enough to evacuate their entire bulges. One aspect that may explain these findings is that Seyferts are relatively low-luminosity AGN. Therefore, outflows may not be powerful enough in these nearby AGN to drive gas out to bulge-radius distances. By exploring outflows in more luminous QSOs, we determine whether it is possible to observe large-scale quasar mode feedback in earlier, more energetic epochs.

Notes:

Ionized gas kinematics in local active galaxies: a comprehensive view of inflows and outflows

Daniel Ruschel Dutra: Universidade Federal de Santa Catarina

In the past decade there has been a growing number of studies suggesting a correlation between the activity of the supermassive black hole (SMBH) at the center of galaxies and the evolution of the galactic bulge. One of the key evidences needed to understand this co-evolution is the radial motion of the interstellar gas, be it the outflow from the AGN, the ejecta from evolved stars, or the inflow from outer parts of the galaxy. To that end we have analyzed the inner kiloparsec of a sample of 26 local ($z < 0.06$) active galactic nuclei (AGN) with spatially resolved optical spectroscopy, using the integral field unit (IFU) of the Gemini Multi-Object Spectrograph (GMOS). Typical spatial resolutions are between 50 pc and 100 pc, with spectral coverage from 4800A to 7000A. We present a complete analysis of the ionized gas for the galaxies in our sample, including kinematical maps, emission line ratios and fluxes. The kinematics show the ubiquitous presence of gas rotation distorted by radial motion of the interstellar gas. Estimates of mass inflow and outflow rates are discussed, and compared to the bolometric luminosity of the AGN, allowing the evaluation of feedback effects on the evolution of the host galaxy.

Notes:

The Inner Regions of AGN: A SINFONI Study of Gas Outflows and Feeding in Local, X-ray Selected AGN

Taro Shimizu: Max Planck Institute for Extraterrestrial Physics

We present new results from our survey of the inner few hundred parsecs of nearby galaxies as part of our Local Luminous AGN with Matched Analogues (LLAMA) project. AGN within the LLAMA sample were selected based on detection at ultra-hard X-rays (14-195 keV) by the Swift/Burst Alert Telescope ensuring the definitive presence of an AGN. We further imposed a redshift ($z < 0.01$) and luminosity ($\log L(14\text{-}195\ \text{keV}) > 42.5$) cutoff to create a complete and volume-limited sample of nearby, luminous AGN. Inactive galaxies were chosen carefully by matching in redshift, host galaxy morphology, inclination, and stellar mass to create a clean sample with which to compare to the AGN. LLAMA AGN and inactive galaxies were observed with VLT/SINFONI using adaptive optics producing high spatial resolution integral field unit spectra in the H and K band. This unique IFU data allows for analysis of a suite of NIR emission lines including [FeII], H_2 (1-0) S(1), [Si VI], and Br-gamma to probe the ionized and warm molecular gas in the circumnuclear region as well as CO absorption lines to probe the stellar disk. I will present initial results from our study including the prevalence of AGN outflows along with their geometry, kinematics, and mass outflow rates and compare the mass, state, and excitation mechanisms of circumnuclear gas between AGN and inactive galaxies. Finally, I will discuss our results in the context of AGN fueling and feedback and provide insight on interpreting similar data at higher redshift.

Notes:

The Keck OSIRIS Nearby AGN Survey: The Role of AGN-driven Outflows in the Evolution of Seyfert Galaxies

Francisco Muller-Sanchez: University of Colorado at Boulder

I present the first results from the KONA survey, which uses the integral field unit OSIRIS plus LGS-AO to probe down to scales of 5 parsecs in a sample of 40 Seyfert galaxies. In this talk, I will describe recent work showing how AGN interact with their host galaxies. We find that AGN-driven outflows of ionized gas are ubiquitous, and that biconical models of radial outflow provide a good fit to the spatially resolved kinematics. The mass outflow rates are 2-3 orders of magnitude greater than the SMBH accretion rates, but are comparable to the estimated inflow rates to the central 25 pc, suggesting that AGN feedback suppresses accretion onto the SMBH and that AGN feedback has a strong impact on the turbulent ISM near the SMBH, probably disrupting the conditions for star formation. Finally, with complimentary Chandra and HST images our observations establish whether or not the outflow extends deep into the host galaxy, and provide direct evidence of the ways in which the outflows of ionized gas interact with the circumnuclear ISM, either by creating cavities of molecular gas, or by launching molecular outflows.

Notes:

A high fraction of double-peaked narrow emission lines in powerful active galactic nuclei

Xin Liu: University of Illinois at Urbana-Champaign

1 per cent of redshift z ~ 0.1 active galactic nuclei (AGNs) show velocity splitting of a few hundred km/s in the narrow emission lines in spatially integrated spectra. Such line profiles have been found to arise from the bulk motion of ionized gas clouds associated with galactic-scale outflows, merging pairs of galaxies each harbouring a supermassive black hole (SMBH), and/or galactic-scale disc rotation. It remains unclear, however, how the frequency of narrow-line velocity splitting may depend on AGN luminosity. Here we study the correlation between the fraction of Type 2 AGNs with double-peaked narrow emission lines and AGN luminosity as indicated by [O III] λ5007 emission-line luminosity $L_{[O\ III]}$. We combine the sample of Liu et al. at z ~ 0.1 with a new sample of 178 Type 2 AGNs with double-peaked [O III] emission lines at z ~ 0.5. We select the new sample from a parent sample of 2089 Type 2 AGNs from the SDSS-III/Baryon Oscillation Spectroscopic Survey. We find a statistically significant (~4.2σ) correlation between $L_{[O\ III]}$ and the fraction of objects that exhibit double-peaked narrow emission lines among all Type 2 AGNs, corrected for selection bias and incompleteness due to [O III] line width, equivalent width, splitting velocity, and/or equivalent width ratio between the two velocity components. Our result suggests that galactic-scale outflows and/or merging pairs of SMBHs are more prevalent in more powerful AGNs, although spatially resolved follow-up observations are needed to resolve the origin(s) for the narrow-line velocity splitting for individual AGNs.

Notes:

Moderate Luminosity AGN as Drivers of Feedback

Rebecca Nevin: University of Colorado, Boulder

While high luminosity quasar-driven outflows are commonly invoked as a means of driving feedback in galaxies, these are extreme cases, and the contribution of moderate luminosity AGN outflows to feedback is still unclear. I will present a sample of 18 moderate luminosity AGN outflows, which I have observed with optical longslit spectroscopy and modeled as biconical outflows using an analytic Markov Chain Monte Carlo method. From the geometry and kinematics of the models, I find that these moderate-luminosity AGN outflows are large and energetic. The biconical outflows axes are randomly oriented with respect to the photometric major axis of the galaxy, implying a randomly oriented and clumpier torus to collimate the outflow, but the torus also allows some radiation to escape equatorially. I find that 16/18 (89%) of the AGN outflows are energetic enough ($L_{KE}/L_{bol} > 0.5\%$) to drive a two-staged feedback process in their host galaxies. All of these outflows geometrically intersect the photometric major axis of the galaxy, and 23% of outflow host galaxies are significantly redder or have significantly lower specific star formation rates when compared to a matched sample of active galaxies. Since moderate luminosity AGN are common in the local universe (10% of the AGN population, whereas high luminosity AGN are only 1% of the population), this suggests that moderate luminosity AGN may play an important role in driving feedback in the universe.

Notes:

Day Four: Thursday, June 29th

Session V: Galactic Scale Outflows and Feedback

Chair: Daniel Proga

Ubiquitous, Spatially Resolved Quasar-Mode Feedback in Nearby Quasars and Correlations with Black Hole Properties

David Rupke: Rhodes College

Spatially-resolved examples of quasar-mode feedback in nearby Type 1 quasars have to date been few and far between. I will present results from a deep integral field spectroscopic survey of kpc-scale ionized and neutral outflows in luminous, radio-quiet, Type 1 AGN at z < 0.3. We find massive, energetic, AGN-driven outflows in 90-100% of our sample. With maximum sizes of 3-10 kpc, maximum velocities of 500-2500 km/s, and mass outflow rates of 20 to > 1000 Msun/yr, these outflows have the ability to prevent future mass accretion onto nearby supermassive black holes. When combined with observations of nearby Seyferts, we find that outflow properties correlate with black hole properties, pointing to black holes of higher mass but lower Eddington ratio being more efficient at providing negative feedback.

Notes:

Molecule formation in AGN-driven galactic winds

Alex Richings: Northwestern University

Observations of AGN host galaxies have detected fast molecular outflows, with velocities up to ~1000 km/s. However, the origin of these molecular outflows is currently unclear. One possibility is that they are formed from molecular gas that is swept up from the host galaxy by the AGN wind. However, previous studies have suggested that molecular clouds that are swept up by an AGN wind are unlikely to survive being accelerated to such high velocities. An alternative scenario is that molecules may form within the AGN wind material itself. I will present a suite of 3D hydrodynamic simulations of an idealised AGN wind that we have run to explore this scenario. These simulations are coupled to a time-dependent chemical model to follow the creation and destruction of molecules, including H2, CO, OH and HCO+. I will show that molecules do form within the wind, with molecular outflow rates up to 30 Msol/yr after 1 Myr. This is sensitive to the ambient ISM density, metallicity, and AGN luminosity. I will also show predictions for observable CO and OH lines computed from our simulations using a radiative transfer code in post-processing, and I will compare these to observations.

Notes:

The case of the galactic wind in 1H 0419-577

Laura Di Gesu: Netherlands Institute for Space Research, Utrecht

The Chandra satellite observed the Seyfert 1 galaxy 1H 0419-577 for the first time in May 2016. This intriguing AGN is known to host a kpc extended outflow, that is seen in the O III image, in the UV, and in the X-ray spectrum (Di Gesu et al. 2013). Using the Chandra ACIS-S image we were able to resolve extended soft X-ray emission. Soft X-ray emitting material is detected with Chandra up to a distance of at least 10 kpc from the bright Seyfert nucleus. We will discuss possible scenarios for the physical nature of the extended emission, focusing on how it could be linked to the galactic wind.

Notes:

Circumnuclear gaseous kinematics and excitation of four local radio galaxies

Guilherme S. Couto: UFSC

We present our results using optical integral field spectroscopy of four nearby ($z < 0.07$) radio galaxies obtained with GMOS in Gemini North and South telescopes. The field-of-view probes a circumnuclear region of ~3.5"x5", with average spatial resolution of ~0.6". In this presentation, we will resume our results for two galaxies of our sample, Arp 102B and Pictor A, which are already published (Couto et al. 2013, 2016), as well as discuss the preliminary results for the other two, 3C 33 and 4C +29.30. While these galaxies present different characteristics, like radio jet morphology, they display in common signatures of interactions or merger events. For Pictor A, e.g., we find unusually low [N II]6584/Hα ratio (0.15 - 0.25), suggesting low metallicity of the gas, not expected in AGNs (Active Galactic Nuclei). This suggests an accretion of gas through an interaction event, in agreement with the tidal tail observed by Gentry et al. (2015). The presence of more than one kinematical component in the galaxies of our sample suggests that mechanisms of feeding or feedback are dominating the central region. Although we estimate low energetic input of the radio jet in the circumnuclear gas (outflow kinetic power of $\dot{E} < 1\% \, L_{bol}$), we do observe indications of jet-cloud interaction, usually forming extended emission-line regions. This is the case of Arp 102B, where apparent nuclear spiral arms traced by ionized gas is the result of circumnuclear gas being pushed by the radio jet. We also present resolved diagnostic diagrams for these galaxies using the optical emission-lines, and the comparison with shocks and photoionization models, which suggests more presence of shocks in regions closer to the radio jet, but also contribution of photoionization.

Notes:

Molecular Outflows and Feedback in the Local Universe

Eckhard Sturm: Max Planck Institute for Extraterrestrial Physics

This presentation will summarize recent results from the SHINING project on molecular outflows in local ULIRGs (AGNs and Starbursts) as traced by OH, CO and [CII]. I will present the observations and discuss the advantages and disadvantages of these complementary tracers. Evidence for, and statistics and simple correlations of outflow measures will be demonstrated. Outflow masses and energetics will be derived, and the source and mechanism(s) will be discussed (AGN and/or star formation driven, momentum and/or energy conserving mechanism). Finally, I will analyse the effect on the environment (mass loading, depletion time).

Notes:

Massive molecular gas flows and AGN feedback in galaxy clusters

Helen Russell: Institute of Astronomy, Cambridge

Powerful radio jets launched by a central supermassive black hole pump a substantial amount of energy into their host galaxies and cluster environment. This feedback from the central AGN is thought to suppress gas cooling and star formation at late times to regulate the growth of massive galaxies and cooling of their surrounding hot atmospheres. The most massive galaxies, located at the centres of rich clusters, often host substantial reserves of molecular gas exceeding that found in gas-rich spirals, which are likely fuelling star formation and the black hole activity. The structure of these molecular reservoirs can now be resolved with ALMA to understand how these processes are regulated. Our ALMA Early Science observations revealed molecular gas filaments extending 5-15 kpc with masses of 10^9 to a few 10^{10} solar masses, which likely formed from gas cooling out of the clusters' hot atmospheres. I will present new ALMA observations of extended molecular filaments in the Phoenix, PKS0745-191 and Abell 1795 central cluster galaxies, which are drawn up around giant jet-blown radio bubbles. Their smooth and narrow velocity fields are consistent with ordered molecular gas flows around the bubbles and show that radio jets interact with cold, dense molecular gas as well as the hot, diffuse intracluster medium.

Notes:

Radiation Hydrodynamics of Dust-Driven Galactic Winds

Dong Zhang: University of Virginia

Galactic winds are ubiquitous in most rapidly star-forming galaxies. They are crucial to the process of galaxy formation and evolution, regulating star formation, shaping the stellar mass function and the mass-metallicity relation, and enriching the intergalactic medium with metals. Although important, the physics of galactic winds is still unclear. Many theoretical mechanisms have been proposed. Winds may be driven by the heating of the interstellar medium by overlapping supernovae explosions, or the radiation pressure by continuum absorption and scattering of starlight on dust grains. In this talk I will focus on molecular outflows driven by radiation pressure on dust. I will present radiation hydrodynamic simulations of momentum coupling between dusty gas and radiation field in a rapidly star-forming environment. In contrast to previous work using flux-limited diffusion algorithm, we apply the variable Eddington tensor algorithm which shows stronger momentum coupling between gas and radiation. The momentum transfer from the radiation field to the gas is not merely ~ L/c, but amplified by a factor of $1 + \eta\ \tau_{IR}$ where L and τ_{IR} are the radiation luminosity and the integrated infrared optical depth through the system, and η ~ 0.5 - 0.9. I will also talk about our recent hydrodynamic simulations of molecular cloud acceleration due to radiation force. We find that radiation pressure may be an important mechanism for driving winds in rapidly star-forming galaxies and starbursts.

Notes:

Increasing the coupling efficiency between the AGN driven winds and ICM through anisotropic thermal conduction

Rahul Kannan: MIT

Feedback from central supermassive blackholes is often invoked to explain the low star formation rates in massive galaxies at the centers of galaxy clusters. However, the detailed physics of the coupling of the injected feedback energy with the intracluster medium is still unclear. Using high-resolution magnetohydrodynamic cosmological simulations of galaxy cluster formation, we investigate the role of anisotropic thermal conduction in shaping the thermodynamic structure of clusters, and, in particular, in modifying the impact of black hole feedback. Stratified anisotropically conducting plasmas (such as the ICM) are formally always unstable, and thus more prone to mixing, an expectation borne out by our results. The increased mixing efficiently isotropizes the injected feedback energy which in turn significantly improves the coupling between the AGN driven winds and the intracluster medium. This reduces the star formation rate by more than an order of magnitude, and results in earlier quenching despite an overall lower amount of feedback energy injected into the cluster core. With conduction, the metallicity gradients and dispersions are lowered, aligning them better with observational constraints. The efficient coupling also allows the cluster to maintain low entropy cores, providing exciting insights into the origin of the classic cool core/non-cool core dichotomy in clusters.

Notes:

How to Quench a Galaxy

Michael Tremmel: University of Washington

Galaxy "Genetic Modification" (GM) is a new breakthrough method that provides the ability to conduct controlled numerical experiments varying a halo's assembly history (Roth+ 2016). We present the first application of GM, combined with a new model for supermassive black hole (SMBH) physics (Tremmel+ 2016) that significantly improves on previous implementations of BH formation, dynamics, and accretion. Using this powerful approach we propose a unifying model where SMBH feedback interacts with strong mergers to provide a major mechanism for quenching massive galaxies (Pontzen+ 2016). We test these predictions with results from a larger, uniform sample of galaxies from the Romulus25 cosmological simulation, examining the impact of this mechanism in the formation of the red sequence across cosmic time.

Notes:

Poster Presentations

1. On the efficiency of line-driving of AGN winds
Randall Dannen: University of Nevada, Las Vegas

One of the main physical mechanisms that could drive mass outflows in AGN is radiation pressure on spectral lines. Although this mechanism is conceptually straightforward to understand, the actual magnitude of the radiation force is very challenging to compute because the force depends on physical conditions of gas and the strength, geometry, and SED of the radiation field. Here we present results from our photoionization and radiation transfer calculations of the radiation force using AGN type SEDs for both the ionizing and driving radiation fields. We use the photoionization code XSTAR and take into account the most up-to-date and complete atomic data and line list. We discuss implications of our results in the context of AGN winds that are observed in the UV and X-ray bands.

2. X-ray Insights into Mini Low Ionization Broad Absorption Line Quasars
Viraja Khatu: The University of Western Ontario

In a quasar, accretion of matter onto the central supermassive black hole is often accompanied by energetic gas outflows. Evidence for this comes from the blue-shifted ultraviolet broad absorption-line (BAL) features with velocity widths greater than 2000 km/s observed in the spectra of a significant fraction of optically selected quasars. Mini low-ionization broad absorption-line (mini-LoBAL) quasars show absorption-line features with velocity widths between 600 km/s and 2000 km/s, where absorption occurs in both low-ionization (here, He I* and Mg II) and high-ionization transition lines. We study a sample of ten mini-LoBAL quasars from the Sloan Digital Sky Survey (SDSS) Data Release 7 with their Chandra X-ray and rest-frame optical-near ultraviolet observations taken close in time with each other. Our goal is to examine their X-ray properties in the light of their outflow properties to understand if the objects in this sub-class display behavior more similar to the LoBAL quasars with heavy absorption in X-rays or the mini-BAL quasars with weak X-ray absorption. Our first results indicate some intriguing differences within our sample with links between their X-ray and optical properties.

3. Constraining the Launching Radius of the Ionized Outflow in NGC 3783
Robyn Smith: University of Maryland

Ionized absorption in the X-ray spectra of Seyfert galaxies displaying the hallmarks of outflowing material has been well-known since the advent of some of the earliest X-ray satellite missions. Now using an optimized extraction technique, we present some of the highest S/N and resolution Chandra spectra to date of NGC 3783. We model the spectra in a physically-motivated and self-consistent way with the photoionization code XSTAR and find that including broadened re-emission provides a better fit than absorption alone. By assuming that the broadening of the emission lines is due to the Keplerian rotation of the accretion disk, we are able to place constraints on the launching radius necessary parameter for estimating the mechanical power of the wind.

4. Testing Accretion Disk Wind Models of BALQSOs with SDSS Spectra
Jack Gabel: Creighton University, Physics Department

We present tests of accretion disk wind models for AGN mass outflow systems using data from the Sloan Digital Sky Survey quasar spectral database. We base our analysis on absorption line and emission properties measured for Broad Absorption Line quasars (BALQSOs). This includes absorption equivalent widths, outflow velocity extremes and ranges, and absorption depths from the literature. We investigate the relationships between these measured properties using correlation analysis, and compare the results to specific predictions from accretion disk wind models. We find that the tests generally support the trends of these properties predicted by accretion disk wind models. We explore how these measured properties can then be used to constrain outflows in future studies.

5. Constraining Outflow Location in FeLoBALs Using Spectral Synthesis Program SimBAL
Francis MacInnis: University of Oklahoma

Quasars with broad absorption lines (BALQSOs) are often the target of outflow studies because these features are clear markers of energetic winds. Within this population is a class known as FeLoBALs, named for the FeII broad absorption lines they have along with the low ionization lines of the LoBAL class. They are a prime target for quantifying outflow strength because of their multiple broad absorption lines. Additionally, they are almost always reddened with high IR luminosity, hinting that they may be a transition phase in galactic evolution. We analyzed FeLoBALs using SimBAL, a program for creating synthetic spectra from a grid of Cloudy models. The observed spectra were fitted to the closest synthetic spectra in parameter space. These techniques were used to determine the density of the outflows, and constrain their distance from the central engine.

6. A New Analysis of the Quasar PG 0946+301
Donald Terndrup: Ohio State University

We present a spectrum-synthesis analysis of the high-quality ultraviolet spectrum of PG 0946+301 (Arav et al. 2001). We focus on the sensitivity of derived quantities such as ionization state and column density to the treatment of velocity structure in the outflow, and discuss previous claims for a large overabundance of phosphorus.

7. Models for the Profiles of Intrinsic Narrow Absorption Lines in Quasar Spectra
Michael Eracleous: The Pennsylvania State University

Intrinsic Narrow Absorption Lines (NALs) are found in 40-50% of quasars at z~1.5-5. The lines originate in compact parcels of gas that are often smaller than the quasar continuum source. The apparent outflow velocity and ionization of the absorbers suggest a connection with a quasar outflow. We construct models for the profiles of NALs and compare them with observations. We input a velocity and density field for the outflowing gas and a spectral energy distribution for the ionizing radiation. We divide this gas into thin layers and use the code Cloudy to compute the ionic populations of each layer, allowing the inner layers to filter out the far-UV photons. We assume that the background continuum source is the inner accretion disk, hence we model the dimensions and brightness profile of this source with wavelength. Thus, we compute the profiles of absorption lines by following the attenuation of rays from each pixel of the background source passing through the absorber. We produce NAL profiles for several families of models including thin outflowing filaments, a spray of small parcels, and a numerically computed model for a radiatively-accelerated wind. For the first two models, the model absorbers have properties consistent with theoretical predictions and yield synthetic NAL profiles in agreement with observations. However, some fine tuning of the size distribution, density profile, and metallicity of the parcels is needed. These results are also sensitive to the properties of the shielding gas. NALs from the numerically computed outflows resemble the observed systems in many ways. We recover examples of strong CIV, NV, and OVI systems with weak/absent SiIV. The FWHM and complexity of the synthetic profiles resemble the observations. However, the modeled lines do not exhibit partial covering because of the low resolution of the original hydrodynamic simulation. Moreover, the velocities of synthetic NALs differ substantially from the observations; they are either at much lower or higher velocity than the observed systems (~100 km/s or ~20,000 km/s).

8. The Distance of Quasar outflows: VLT/X-SHOOTER Survey
Xinfeng Xu: Virginia Tech

We observed 13 BAL and Mini-BAL quasars using the VLT X-Shooter spectrograph. In 7 of these we find outflow troughs from S IV and SIV*. Using collisional excitation models of the measured S IV and S IV column densities, we determine the electron number density of the outflow; and combining this value of ne with photoionization simulations, we derive the distance of each outflow from the central source. We find that 6 out of 8 outflows (one quasar show two such outflows) are located at a distances of more than 100 pc. from the central source. The spectral region covering the S IV and S IV* troughs was not observed in our targets prior to the VLT observations; and therefore this sample is unbiased towards a specific distance scale. Thus, these results are representative (albeit in a small sample) for the general population of high ionization BAL and mini-BAL outflows.

9. Intrinsic, Narrow N V Absorption Reveals a Clumpy Outflow in z < 0.4 Radio-Loud Quasars
Rajib Ganguly: University of Michigan-Flint

An inspection of HST archival quasar spectra taken with COS/G130M or G160M reveals a curious result. While roughly 27% of radio-quiet quasars show intrinsic N V narrow absorption systems near the quasar redshift ("associated" systems), thought to trace the quasar outflow, nearly none of the radio-loud quasars show N V absorption. This is at odds with historical studies of C IV absorption lines, which show that steep-spectrum radio-loud quasars appear to show a plethora of associated systems. Interestingly, essentially all of the radio-loud quasars for which N V absorption can be detected have compact morphologies as sampled by FIRST 1.4 GHz imaging and comparatively flat radio spectra. This implies that we are viewing more face-on orientations which bias us against seeing outflows in absorption. We are using the HST to carry out a spectroscopic investigation of the incidence of N V associated systems in radio-loud quasars as a function of orientation. We present a progress report on this survey which has already turned up an unexpectedly interesting result - evidence of a clumpy outflow.

10. Understanding Low-Redshift Quasar Outflows Using Intrinsic NV Absorption Lines
Chris Culliton: Penn State

Quasar outflows are important for understanding the accretion and growth processes of the central black hole. Furthermore, outflows potentially have a role in providing feedback to the galaxy, and halting star formation and infall of gas from the IGM. The geometry and density of these outflows remain unknown, as well as the relation between density, ionization, and velocity of the NAL gas. Having searched ultraviolet spectra from the Hubble Space Telescope's Cosmic Origins Spectrograph archive we have located intrinsic N V absorption systems in z < 0.4 quasars, with nearly all systems having velocity offsets less than 5000 km/s. We consider the incidence of intrinsic absorbers as a function of quasar properties (optical, radio and X-ray fluxes). We also compare the properties of those quasars in whose spectra we found intrinsic absorption with respect to those in which we did not.

11. Radio Weather Report: AALs and BALs say it's going to be windy
Robert B. Stone: Drexel University

We investigate the nature of quasar outflows in the form of both broad and narrow absorption lines using data taken as part of the Sloan Digital Sky Survey (SDSS). We know that quasars are broadly diverse with a wide range of differing intrinsic properties, but only a small fraction of them are strong radio sources. We explore this small quasar parameter space in hopes that it can give unique insight into the nature of outflows (or at least a particular subset of them). Working under the assumption that the narrow absorption lines are caused by outflowing material, we investigate the velocity distributions of these absorbers. While the extreme high velocity absorbers are clearly caused by intervening galaxies along our line-of-sight, and thus not relevant to our study, we focus on the low velocity absorbers, called associated absorption lines (AALs), which we believe to be intrinsically part of the QSO. We look for correlations of these outflows with the radio properties of the quasars, which can potentially reveal a physical connection between the quasar's accretion physics and its outflows. Our ultimate goal is to understand how outflows from quasars change as a function of line-of-sight orientation, mass, accretion, and spin of the black holes that fuel them.

12. An Update on the Intrinsic Absorption in Nearby AGN
Jay Dunn: Perimeter College - Georgia State University

We present a survey of the intrinsic UV absorption lines in active galactic nuclei (AGN). We limit our study to the ultraviolet spectra of type 1 AGN with a redshift of $z < 0.15$ as a continuation of the Dunn et al. (2007, 2008) and Crenshaw et al. (1999) samples. We identify approximately 80 type 1 AGN that fit our redshift specifications with Cosmic Origin Spectrograph (COS) observations in the Mikulski Archive for Space Telescopes (MAST) database. We process, normalize, and identify all of the intrinsic absorption features. From these data, we determine the fraction of type 1 AGN with intrinsic absorption in this redshift range and find the global covering factors of the absorbers. We also identify low ionization species as well as excited state lines in two objects. Finally, 7 AGN have multiple epoch observations with COS and/or Space Telescope Imaging Spectrograph (STIS). We use these spectra to investigate the physical properties of the absorbing clouds through variability. Three objects show signs of variation in the absorption troughs and four objects had measurable changes in continuum flux, which has implications on the location of the absorbing material.

13. The Ultraviolet Spectra of Active Galaxies With Double-Peaked Balmer Emission Lines
Michael Eracleous: The Pennsylvania State University

We present the UV spectra of eight nearby AGNs with broad, double-peaked Balmer emission lines in their optical spectra. We find that the Mg II UV lines have similar widths and profiles as the optical Balmer lines but the higher-ionization UV lines as well as Lyα have single peaked and relatively "cuspy" profiles. We find that the Lyα/Hα ratio in double-peaked emitters increases with Eddington ratio; it ranges from less than unity for the objects with the lowest Eddington ratios to a few for objects with Eddington ratios of order a few tenths. We quantify the profile shapes by means of the ratio of widths at half maximum and quarter maximum, which is a proxy for the kurtosis. We find that the kurtosis of the UV lines of double-peaked emitters is substantially lower than that of the same lines of ordinary quasars (i.e., the UV lines of double-peaked emitters are less "cuspy"). We interpret these observational results in the context of a picture where the broad-line region is an accretion disk and its associated wind. We suggest that the relative strengths and profiles shapes of double-peaked emitters correspond to a wind with a small optical depth and small emission measure, which is a consequence of a low Eddington ratio.

14. Stellar Dynamical Modeling of AGN for Comparison with Reverberation Mapping
Caroline A. Roberts: Georgia State University

Supermassive black hole masses are linked to properties of their host galaxies as exhibited by black hole scaling relations. Checks of the consistencies between mass determination methods are integral to extragalactic astronomy. There exists only a small population of comparison objects whose black hole masses can be determined through multiple methods, but such attempts are important for identifying systematic errors within the techniques and producing robust masses. Both stellar dynamical modeling and reverberation mapping have been applied to NGC 4151 (Onken et al. 2014, Bentz et al. 2006) and NGC 3227 (Davies et al. 2006, Denney et al. 2010), and the results from the methods were in agreement. However, both objects are weakly barred and the stellar dynamical modeling orbit superposition code did not yet account for non-axisymmetric orbits. The data must be reexamined with a bar-optimized code. Construction of such a code is currently underway (Valluri). We will describe our ongoing work to carry out new stellar dynamical modeling of NGC 4151 and 3227 using archival Gemini NIFS and VLT SINFONI IFU observations. These results will represent the best comparisons of stellar dynamical modeling and reverberation mapping techniques to date.

15. Responsivities for Reverberation Mapping Calculations
Tim Waters: University of Nevada Las Vegas

By exploiting spectral information gathered in the time domain, reverberation mapping is a powerful technique that can be used to constrain the global dynamics of the broad line region. While inversion methods attempt to recover this information directly, dynamical modeling efforts begin by constructing models for the distribution of responsive gas. Sophisticated techniques have been developed to directly compare these models with observations, but the construction of the physical models themselves is lacking in sophistication. We have developed methods to self-consistently combine hydrodynamical simulations and photoionization calculations, the latter being necessary to realistically model the responsivity of the gas. We present our recent efforts on these line responsivity calculations.

16. Extreme Outflows in Extremely Red Quasars
Frederick Hamann: University of California, Riverside

Red quasars are candidate young objects participating in the early stages of massive galaxy formation. Our team recently discovered a unique population of extremely red quasars (ERQs) at redshifts 2-3 in the SDSS-III/Baryon Oscillation Spectroscopic Survey (BOSS). We find that ERQ have a suite of peculiar line properties indicative of powerful outflows: i) a high incidence of broad outflow absorption lines (>30-68% compared to 14% in similarly-luminous quasars at these redshifts). ii) a high incidence of large CIV emission-line blueshifts (with shifts >2500 km/s roughly fifty times more common in ERQs than normal quasars and reaching 8740 km/s in one ERQ), and iii) the broadest and most blueshifted [OIII] 5007 lines ever reported with FWHMs and blueshifted wings up to 5000 km/s. The broad emission lines also have characteristically very large equivalent widths, odd flux ratios such as NV > Lya, and peculiar "wingless" line profiles. These properties and the SED shapes are not consistent with normal quasars behind a dust-reddening screen. We argue that the ERQs have characteristically extreme physical conditions that drive powerful outflows across the line-forming regions on a wide range of spatial scales, from the traditional broad-line regions near the accretion disk to the low-density [OIII] gas at distances >~1 kpc. The underlying reasons for the extreme physical conditions are not know, but they might be related to high accretion rates and/or high metallicities during a dusty blowout stage of quasar/galaxy evolution.

17. Optical and infrared radiation pressure on dust and gas around AGN as divers of dusty winds
Marta Venanzi: University of Southampton

Parsec-scale polar emission signatures seen in the infrared continuum of many nearby AGN suggest the presence of dust in a region generally associated with outflowing gas. We present an analytical model to investigate the influence of radiation pressure acting on dusty gas on these small scales around an AGN, outlining the regime for which radiatively driven outflows become possible. The main components of the model under consideration are an AGN and an infrared radiating dusty disk, the latter being the primary mass reservoir for the outflow. The analysis is developed within the force domain, accounting for both gravity and the AGN radiation as well as the re-radiation by the hot dusty gas clouds themselves. The analytical model is based on CLOUDY photoionisation calculations to derive the radiative acceleration experienced by the dusty gas. We show that a combination of neutral gas and dust opacities is sufficient to push material out to large scales. However, the strength and direction of such a dusty outflow will depend on the Eddington ratio and column density of dust clouds in the AGN vicinity. The model is complementary to our ongoing development of radiative hydrodynamic simulations and can be tested against near- and mid-infrared observations of AGN.

18. Extended Gas Kinematics and Ionization Mechanisms in the Seyfert 2 Galaxy Markarian 3
Camilo Machuca: University of Wisconsin - Madison

Recent studies of gas kinematics and ionization mechanisms in the Seyfert 2 galaxy Markarian 573 have shown that the narrow-line region (NLR) gas is AGN-ionized up to several kiloparsecs and is kinematically dominated by host-disk rotation at distances larger than about one kiloparsec. In order to further understand the connection between AGN and their host galaxies, we present similar analysis on the more compact and kinematically complex Seyfert 2 galaxy Markarian 3. This work is based on long-slit spectra observed with the Dual Imaging Spectrograph (DIS) on the 3.5-m ARC telescope at the Apache Point Observatory. We compare the large-scale kinematic results to inner-region kinematics obtained with the Gemini Near infrared Field Spectrometer (see Pope et al.), identify regions of rotation- and outflow-dominated kinematics, and use BPT diagnostics to determine ionization mechanisms as a function of distance from the nucleus.

19. The Limited Impact of Outflows: Integral-field Spectroscopy of 20 Local AGNs
Helene Flohic: University of the Pacific

To investigate AGN outflows' feedback on star formation, we perform integral-field spectroscopy of 20 nearby luminous type 2 AGNs with strong outflow signatures. We obtain the maps of the narrow and broad components of the [O III] and Hα lines, and we estimate the energetics of the gas outflows. The outflow energetics are consistent with the theoretical expectations for energy-conserving outflows from AGNs, yet we find no supporting evidence of instantaneous quenching of star formation due to the outflows.

20. A Survey of Kiloparsec-scale Outflows in Nearby Unobscured Quasars
Jessie Runnoe: University of Michigan

Nearly 20 years ago it was proposed that feedback from active galactic nuclei (AGN) could drive the co-evolution of supermassive black holes and their host galaxies. However, it is still unknown how ubiquitously or to what degree the large amounts of energy and momentum that are produced by AGNs can actually couple to the surrounding interstellar medium of the host galaxy. That is, the prevalence and properties of AGN-driven outflows on kiloparsec scales are not well characterized. With this motivation, we have undertaken a multi-wavelength observing program to study the multiphase outflows of nearby (z~0.1) Type 1 quasars. As the nearest unobscured supermassive black holes that approach the accretion rates seen in AGN at the epochs of peak accretion activity at high redshift, these are prime laboratories for studying quasar-mode feedback in galaxies. Targets for this survey are all Type-1 quasars selected from a parent sample of nearby ultraluminous infrared galaxies and Palomar-Green quasars. We have begun observations with the NOrthern Extended Millimeter Array (NOEMA) to resolve molecular outflows and with Magellan and Gemini to trace outflows of ionized gas using integral field spectroscopy. I will outline the design of our survey, and present initial results from this ongoing effort.

21. The effect of AGN feedback in the migration timescale of super massive black holes binaries
Luciano del Valle: Institute d'Astrophysique de Paris

Motivated by the theoretical and observational evidence that after a major merger of gas-rich galaxies a massive gaseous disk with a SMBH binary will be formed in the nuclear region of the remnant, we study the interaction between an unequal mass binary and an isothermal circumbinary disk. We focus our study in the transport of angular momentum from the binary to the disk and how this transport can result on the formation of a cavity or gap in the gaseous disk. We propose that, for comparable mass binaries, this exchange of angular momentum is driven by the gravitational interaction of the binary and a strong non-axisymmetric density perturbation that is formed in the disk as response to the presence of the gravitational field of the binary. We compare the efficiency of this gravitational torque on extract angular momentum from the binary with the efficiency of redistribution of the extracted angular momentum in the disk to derive a gap-opening criterion. We run a set of SPH simulations of binaries embedded in isothermal gaseous disks to test our gap-opening criterion. We find that our gap-opening criterion successfully predicts in which simulations a gap will form on the disk. We also run simulations of SMBH binaries with active SMBHs. We model the AGN feedback using a momentum driving prescription and we explore the effect of this feedback in the formation of the gap and in the subsequent migration of the binary.

22. Inferring properties of outflows associated with tidal disruption events via analysis of optical and UV spectra

Nathaniel Roth: University of Maryland

Tidal disruptions of stars that pass near super-massive black holes offer a fresh perspective on the processes that govern AGN outflows. The fallback of material post-disruption is expected to be super-Eddington in a large fraction of such events, suggesting that radiatively launched outflows should be common in such systems. Both relativistic jets and non-relativistic outflows have been identified in several tidal disruption events based on their gamma ray and radio emission. However, inferring outflow properties from optical and UV spectra has remained a challenge. In this poster I will present a new approach to gleaning gas kinematical information from such spectra based on radiative transfer calculations specially designed for the high-density stellar debris resulting from stellar disruption.

23. Black Hole Masses: Comparing Results from Reverberation Mapping and Stellar Dynamics

Misty Bentz: Georgia State University

Black hole mass measurements play a key role in our understanding of galaxy formation and evolution. For quiescent galaxies, dynamical modeling is typically used to constrain black hole masses, while reverberation mapping is the technique of choice for active galaxies. But because of the disparate requirements that must be met for each of these techniques, there have been only two attempts to carry out both in the same galaxy. I will describe our ongoing work to identify a sample of galaxies where both techniques can be applied and where their black hole masses may be directly compared. Such tests are important for identifying any biases that may exist within the cosmological black hole mass scale.

24. Jets Launching Radius in Low-Power Radio-Loud AGNs

Truong Le: Berry College

Using our self-consistent theory for the production of relativistic outflows, we estimate the jet launching radius of 22 low-power radio-loud AGNs based on the observed jet powers and their inferred mass accretion rates. We will present (1) the fraction of the accreted energy that is required to convert the accreted mass to relativistic-energy particles for the production of the jets near the horizon, (2) the jets launching radius correlation with the observed mass accretion rate and jets power, and (3) the quenching radius where no jets/outflows formation is possible.

25. Co-spatial UV-Optical HST/STIS Observations of Seven Planetary Nebulae: Spectral Analysis and Cloudy Modeling

Timothy Miller : University of Oklahoma

We present an analysis of seven spatially resolved planetary nebulae (PNe), IC 2165, IC 3568, NGC 2440, NGC 3242, NGC 5315, NGC 5882, NGC 7662, from observations in the Cycle 19 program GO 12600. This

project had two main goals: (1) investigate to what extent PNe are chemically homogeneous; and (2) provide physical constraints on the central star properties of each PN. We accomplished the first goal by using HST/STIS spectra to measure the abundances of seven elements in numerous spatial regions within each of the planetary nebula. The second goal was achieved by computing a photoionization model with Cloudy of each nebula while using our observed emission line strengths as constraints. The major finding of our study is that the nebular abundances of He, C, N, O, Ne, S, and Ar are consistent with a chemically homogeneous picture for each PN. Additionally, we found through experimenting with three different density profiles (constant, Gaussian, and Gaussian with a power-law) that the determination of the best value for the central star's temperature and luminosity is only slightly sensitive to the profile choice. Lastly, post-AGB evolutionary model predictions of temperature and luminosity available in the literature were plotted along with the values inferred from the photoionization model analysis to yield initial and final mass estimates of each central star.
We gratefully acknowledge generous support from NASA through grants related to the Cycle 19 program GO 12600, as well as from the University of Oklahoma.

26. A Time-Domain Spectroscopic Survey of Quasars in the Era of LSST

Yue Shen: University of Illinois at Urbana-Champaign

ReSpeQ (Repeat Spectroscopy of Quasars) is a major program included in the After-Sloan-IV (AS4) survey during 2020-2025. Spectroscopic variability in quasars uniquely measures supermassive black hole (SMBH) masses, accretion disk properties, accretion rate changes, dynamical changes in the broad emission line region, outflows and beyond. The ReSpeQ program provides data that are sorely needed to understand quasar accretion flows, which are both an agent of feedback that drives galaxy evolution and also the means by which we measure black hole masses. Spectral epochs sampling timescales from days to more than a decade, and spanning a wide redshift and luminosity range provide information that is completely unavailable to the many current and upcoming photometric time domain imaging surveys, while offering powerful benchmarks for understanding their content. ReSpeQ simultaneously resolves variability from the continuum emission regions of the accretion disk, from the broad emission line regions on both photoionization and dynamical timescales, and from absorption lines that probe powerful kinetic outflows, with three parallel and complementary tiers. We describe the basics of the ReSpeQ survey and its expected science impact in the coming decade.

Additional Notes: