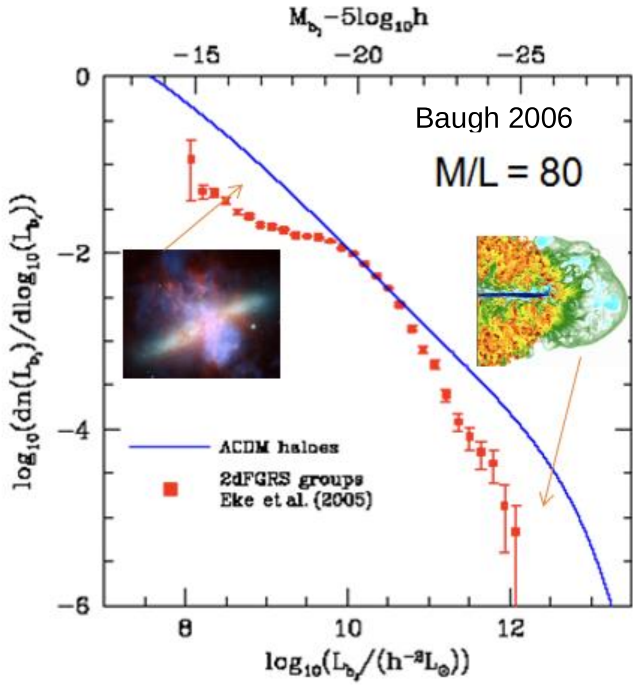
Feedback mechanisms in low-mass AGN

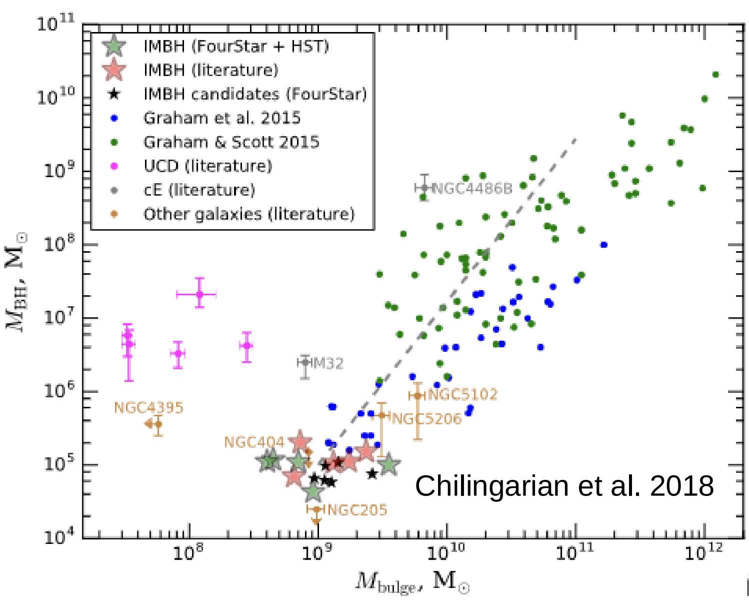
Anne-Laure Melchior (LERMA, SU)
Igor Chilingarian (CfA, Cambridge)

Scientific rationale:



Star formation and dynamics are the main drivers of the secular evolution of local galaxies (e.g. Kormendy & Kennicutt, 2004). Early galaxies, thought to form stars from primordial gas, subsequently merge with each other, accrete gas from cosmic filaments but also recycle gas via stellar evolution (e.g. Gott et al. 2005; Bond et al. 2010; Santiago-Bautista et al. 2020). Outflows from star formation or Active Galactic Nuclei (AGN) triggered by the central black hole might account for the inside-out quenching observed in some galaxies (e.g. Kalinova et al. 2021), but gas exhaustion and morphological quenching are also difficult to disentangle (e.g. Belfiore et al. 2016, Martig et al. 2009).

As discussed by Baugh (2006) (right Figure), there is a discrepancy between the observed luminosity function of galaxies (red points) and our knowledge included in numerical simulations (blue curve). As discussed in Behzoori et al. (2013), this is commonly understood as due to the feedback (which was not modeled in 2006). In all types of galaxies, stellar feedback dominated by supernovae winds (with typical velocity of order 100 km/s) is expected to impact mainly small galaxies (like M82 in the above example). In parallel, the AGN feedback, proportional to the mass of the black hole, impacts mostly the massive galaxies (as illustrated by a numerical simulation in the above figure).



The robust correlation between the bulge masses and the central black hole masses (Kormendy & Ho, 2013) is understood as the signature of the co-evolution of the central massive black holes with the spheroids of their galaxy hosts. While the common growth is understood due to gas fueling from merging or filaments, the feedback, if large enough, can stop it. In addition, while this correlation is well understood for black hole masses larger $2\text{x}10^5 M_\odot$, the lower end is still uncertain. Indeed, while stellar-origin black holes are studied below $10^2 M_\odot$, there is a gap between the two mass ranges, that correspond to intermediate mass black holes (IMBH) (see e.g. Green et al. 2020). This correlation is illustrated in the above figure (from Chilingarian et al. 2018). The pink points correspond to ultra-compact galaxies whose bulge stars have most probably been stripped through interactions so their black hole masses are larger than expected, while the colored stars correspond to IMBH candidates.

In **Chilingarian et al. (2018),** a sample of 305 intermediate mass black holes (IMBH) candidates has been published based on the detection of broad-line regions in the Balmer lines typical of type-I AGN. Hence, their black hole mass ($M_{BH} < 2.5 \times 10^5 M_\odot$) has been estimated from optical broad-line Hα. Among this sample composed mainly of isolated galaxies or in small groups, there are 30 objects detected in Chandra and XMM-Newton X-ray data archives and 7 of them have X-ray luminosities indicating that they accrete close to or even above the Eddington limit, i.e. with extremely high accretion rate.

Proposed doctoral research project:

We propose to study host galaxies of rapidly accreting IMBHs. Their properties, including their star formation activity and gas content, will be investigated in order to search for feedback. What is the impact of IMBH nuclear activity on their host galaxies? Can Eddington-limited active IMBHs quench the star formation activity in low-mass galaxies? Or is the quenching only due to supernovae? Can we directly detect signs of recent AGN-related quenching in host galaxies of IMBHs and light-weight SMBHs?

This work will rely on multiwavelength data already available within our collaboration. Spatially-resolved data are already collected for two Eddington-limited IMBH hosts (GMOS-IFU at 8m Gemini-South) and we also observed them with the HST in the framework of our Snapshot survey. For the remaining galaxies, we have long-slit spectra from Keck and Magellan and archival IFU data from MaNGA/SAMI/Califa. All galaxies have either archival or our own X-ray data from Chandra/XMM-Newton and FUV imaging from AstroSat, as listed in the table below.

λ	X-ray	far-UV	near-UV	Optics	near-IR,IR
Instruments	Chandra XMM-Newton AstroSat	AstroSat	GALEX HST	Spectra: SDSS/Keck/Gemini/Magellan Photometry: SDSS/Legacy Survey/HST Snapshot Survey	UKIDSS VISTA WISE Spitzer
Information	Luminosities of the AGN	Host SFR, AGN continuum	Host SFR, AGN continuum	BH mass from broad Hα, structure of host galaxies	Warm dust around AGN
	Multi-wavelength SED				

Self-consistent multi-wavelength spectral energy distribution (SED) modeling will enable to disentangle the effects of AGN and star formation (X-ray to IR or even to radio), relying on tools like X-CIGALE (Yang et al. 2020). In parallel, an analysis of the stellar population will be undertaken with NBursts full spectrum fitting (Chilingarian et al. 2007), to get the kinematics and the mass-to-light ratio. It will then be possible to derive the gravitational potential of the host galaxies with dynamical models and to see if it can hold the gas. For the most favorable candidates, we will propose HI observations to search for atomic gas (MeerKAT). For the most massive ones, we will search for molecular gas (IRAM-30m, NOEMA, ALMA, SMA).

● Baugh, Reports on Progress in Physics, 69, 3101 (2006) ● Behzoori et al., ApJ, 770, 57 (2013) ● Belfiore et al., MNRAS, 461, 3111 (2016) ● Bond et al., MNRAS, 409, 156 (2010) ● Chilingarian et al., MNRAS, 376, 1033 (2007) ● Chilingarian et al., ApJ 863, 1 (2018) ● Gott et al., ApJ, 624, 463 (2005) ● Greene et al., ARA&A 58, 257 (2020) ● Kalinova et al., A&A, 648, 64 (2021) ● Kormendy & Kennicutt, ARA&A, 42, 603 (2004) ● Kormendy & Ho, ARA&A 51, 511 (2013) ● Martig et al., ApJ, 707, 250 (2009) ● Santiago-Bautista et al., A&A, 637, A31 (2020) ● Yang et al., MNRAS, 491, 740 (2020)

Co-supervision proposed for the doctorate work:

The supervisor and co-supervisor have a long-standing collaboration on different topics which have been concluded by publications. Funding has been secured by the co-supervisor at the Center for Astrophysics, Harvard and Smithsonian (Cambridge, USA) using NASA ADAP grant to host a PhD student for 3-6 months per year in 2023-2025.