

Accretion and feedback in the gas of galaxy nuclei fundamentally shape their hosts on scales from the central supermassive black hole to the bulge. However, our own Galactic center (GC), which has long been the only nucleus we can resolve, has a quiescent central black hole and low star formation, giving limited insight into these processes. Now, with the advances made possible with ALMA, I am leading the first parsec-scale comparisons of the gas in the GC and the nearby nuclear starburst galaxy NGC 253. **As a professor at BU, I will build the first sample of resolved galaxy cores to directly probe accretion and feedback processes through their impact on gas properties** while continuing to leverage the proximity of our GC to conduct studies impossible in other galaxies.

Isolating the origin of Extreme Gas Conditions: GC gas properties are unique in our Galaxy, with an order of magnitude higher temperatures^{1–3}, densities^{4,5}, and turbulence^{6,7} than found in the disk. In studying these properties my work is driven by the following questions. All of these projects have data currently in hand for PhD projects.

1. **What sets these conditions?** I lead multiple research programs connecting temperatures and line widths of molecular gas to depth in the central GC potential. This work will identify the turbulent energy driven by accretion and infall, which must be considered when isolating effects of feedback in more active galaxy cores. I am also the PI of a 30 hour ALMA program to make the first measurements of gas density structure for a sample of GC clouds. At BU I will push surveys of temperature and density to the highest resolutions achievable in order to map out the full thermal structure of the GC as a function of scale.
2. **Do these initial gas conditions modify the star formation process in this and other extreme environments?** Using the proximity of the GC to study weak molecular tracers at high spatial resolution, I am leading a study of isotope ratios in the Sgr B2 cloud that are similar to unusually high ¹⁵N and D abundances in primitive solar system material^{8,9}. Over the next five years at BU, my research group will expand GC chemistry studies beyond Sgr B2 to probe the full range of chemistry present in environments with temperature, density and turbulence like high-z galaxies at the peak of star and planet formation¹⁰.
3. **How will conditions in the GC evolve over time?** Due to the proximity of the GC, it is also possible to directly track gas evolution via proper motions. Over the next ten years, I will establish baselines for measuring the 0.05'' per decade GC orbital motions from VLA and ALMA data of methanol masers (these masers are too weak and extended for VLBI, but sufficiently numerous¹¹ for statistically constraining bulk motion). My work will break degeneracies in 3D orbital models^{12,13}, and tightly constrain the accretion rate toward the central parsec, which will determine the future activity of the GC.

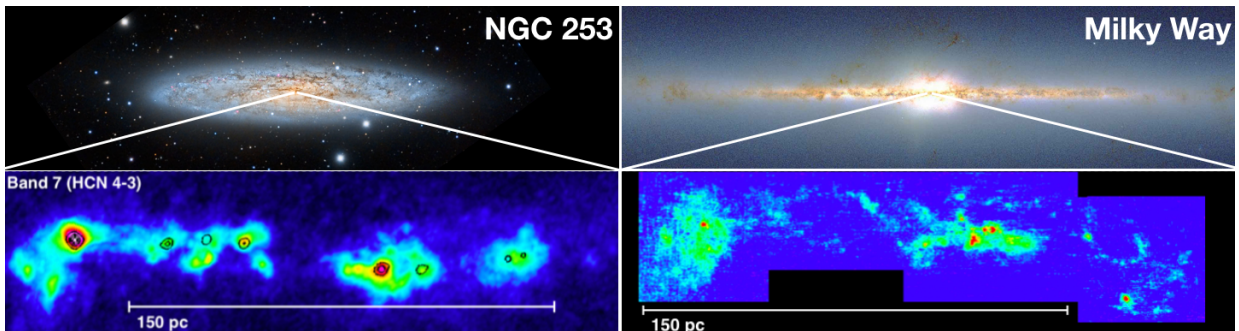


Fig. 1.—: Parsec-scale gas structure in the center of NGC 253 (ALMA) and the Milky Way (ASTE). At BU, I will lead the the first survey of resolved gas in the cores of all spiral galaxies within 5 Mpc visible with ALMA.

Building a Sample of Galaxy Cores: As we can only directly observe temporal evolution on $\lesssim 100$ year timescales in our own GC¹⁴, I am also constructing a sample of resolved galaxy cores in order to probe how molecular gas conditions change with the \sim Myrs duty cycles of activity in these sources. I am currently leading the first comparison of molecular gas on identical 2 pc size scales in the GC and the nuclear starburst of NGC 253 (see Figure 1; data is in-hand and available for PhD projects) and I have a 30 hour ALMA PI project to expand this to an additional band to study the excitation. As NGC 253 also lacks an AGN, these observations will isolate the contribution of the starburst to the gas conditions and directly address the question of whether the processes that set the gas conditions in our own GC are the same as those which dominate in more actively star forming galaxies. Over next five years, the research group I lead will use ALMA and JWST to expand the sample to the cores of a half dozen other major nearby galaxies within 5 Mpc (accessible with ALMA) and begin to isolate the effects of AGN, a bar potential, and metallicity. However, as even extreme local galaxies still do not sample the most intense AGN or star formation activity, I will expand this sample over the next ten years, using an identical observational setup comprising multi-band observations of dense gas tracers beyond CO, to include galaxies more representative of high redshift populations.

Connecting Gas Properties from Low to High Redshift: As I expand the sample of galaxy cores to more distant sources, one goal will be to identify local regions in more nearby sources (e.g., individual star forming regions, or gas very close to a low-level AGN) that are representative of global conditions in more distant and extreme sources. I will conduct detailed characterization of their chemical and physical conditions that will serve as templates for interpreting progressively less resolved galaxy cores, in order to characterize the most likely conditions of the small scale gas in these objects. However, for these templates to be accurately compared to distant sources, it will be critical to determine how low spatial resolution biases the determination of the physical and chemical conditions (e.g., Ref. 15). My primary goal with this work over the next ten years will be to quantify how accurately the true gas conditions revealed by my sub-parsec scale investigations are reflected in properties inferred from ‘unresolved’ averages over the entire galaxy nucleus. The studies my group will lead will constrain the magnitude of scatter or systematic bias by which the small-scale properties indicative of star formation conditions deviate from the conditions inferred on larger scales. My work will yield the most accurate interpretation of conditions in the star forming gas for galaxies in the early universe. As our own GC will allow the highest resolution probes of star forming gas conditions for comparison with the nucleus-averaged properties, the surveys that I will continue to lead for this region will be critical for accurately interpreting observations of the most distant sources.

Ultimately, as a professor at BU, **I will lead a research program that will**

- **Make the highest resolution survey of GC gas, constraining its heating source**
- **Isolate effects of accretion and feedback in molecular gas of nearby galaxy cores**
- **Enable accurate determinations of star forming gas conditions in distant galaxies**

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