Title: THE EVOLUTION OF THE MILKY WAY GALAXY

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Since my first introduction to astronomy, I have yearned to study the hydrodynamical processes of intergalactic and galactic gas. As an undergraduate, I pursued several research projects to prepare for my career in astronomy. Last summer, I began graduate research early with my advisor, Dr. Churchill. Through many discussions of his field, galaxy halo dynamics, I formulated my dissertation topic: to study the gas dynamics of the Milky Way Galaxy and to constrain competing theories of its evolution.

Intellectual Merit: Galaxies are the most fundamental structures in the Universe. Their birth and evolution is driven by how they process their gas. Galaxies form where gas coalesces into structures at the nodes of the cosmic web - the complex intersections of intergalactic filaments and sheets of gas that stretch across the Universe. These collapsing structures become galaxies as they start to actively process the accreting gas. First generation massive stars explode (supernovae), expelling chemically enriched gas outward, while chemically pristine gas continuously accretes onto the galaxy. Much like a fountain spews out water violently into a reservoir that stirs itself and cycles back down, young galaxies actively develop in a similar fashion. These dynamics generate extended active halos surrounding galaxies. The kinematical, chemical, and ionization conditions of these extended gaseous halos provide direct clues to the evoultion of galaxies.

The Milky Way (MW) serves as the keystone for understanding galaxy evolution - as a typical galaxy, it is representative of all galaxies. The MW is the *only* galaxy for which we have the capability to obtain the highest level of detailed information. The gas in the MW comprises a wide range of ionization stages for a multitude of chemical species. Surrounding the MW is the corona, which is built of hot, highly ionized, diffuse layers of gas traced by O VI and C IV ions (Savage 2005, ASP, 331, 3). Neighboring the MW are two smaller satellite galaxies, the Magellanic Clouds. The MW is cannibalizing them by tidally stripping their gas and stars, a process that forms great arcs of gas around the MW. This "Magellanic Stream" is traced by neutral hydrogen (H I) and low ionization species such as Si II and C II (Sembach 2001, AJ, 121, 992). The MW is also surrounded by anomolous clouds with velocities highly peculiar relative to the rotation of the MW. These high velocity clouds (HVCs) are gaseous complexes predominantly observed in H I, Si II, C IV, and O VI (Sembach 2001). They have sizes of several kpc (Braun 1999, A&A, 341, 437), are thought to be rapidly falling into the MW, and are perhaps remnants from the Galaxy's formation out of the cosmic web (Wakker 2001, ApJ, 136, 463). Clearly, the gas surrounding the MW is dynamic and complex with a wide range of ionized regions and densities.

How do we observe and study this gas? Distributed across the sky are nearly a hundred sight-lines to ultra-luminous deep space quasars. Their spectra are uniquely suited to provide the fingerprint signatures of the gas in the MW halo. These fingerprints are patterns of absorption which occurs when various chemical ions in the gas absorb light along its path to Earth. **I propose** a unique approach to characterizing the origin of the halo gas, tidal streams, and HVCs in the MW. I will be guided by my advisor Dr. Chris Churchill, a galactic halo specialist, and Dr. Anatoly Klypin, an internationally recognized expert in cosmological simulations. We will use sophisticated computer simulations of the formation and evolution of the MW in the cosmic web that includes detailed processing of the gas from the stars from within the Galaxy. I will study the formation and evolution of galaxies in a ΛCDM universe using high-resolution cosmological simulations that allow us to resolve sub-Kpc scales. These resolutions are critical to resolve the formation of galactic disks. The simulations are performed using the Eulerian Gasdynamics plus N-body Adaptive Refinement Tree (ART) code (Kravtsov 1997, ApJs, 111, 73; Kravtsov 1999, ApJ, 520, 437; Kravtsov 2004, ApJ, 609, 482). The physical processes implemented in the code include radiative cooling, star formation, metal enrichment and thermal feedback due to type II and type Ia supernovae; the role of supernova feedback at galactic scales is still a matter of debate (Brooks 2006, AAS, 208, 5303; Tassis 2006, PhDT, 2). The simulation follows the formation of a MW-type galaxy in a 10 Mpc h^{-1} box. It has 400,000 dark matter particles in a high-resolution region of 2 Mpc h^{-1} of radius and the hydrodynamics are resolved with more than 13 millions gas cells, yielding a spatial resolution of 100 - 200 pc. The mass resolution is $5 \times 10^6 M_\odot$ and the maximum force resolution achieved is 400 pc at redshift 1 (we can resolve shocks). From this, we will build a library of numerical "galaxies" probing different masses and environments, out to a radius of several Mpc, to determine which prescription best fits the observations of the MW. This process will guide our selection and parametrization of physical processes taking place during the formation of the MW galaxy.

I seek to replicate observational data with these theoretical simulations of the MW. We will run mock quasar sight lines through the MW disk from the solar radius in all directions, generating mock spectra that we will statistically constrain with quantitative results from the *Hubble Space Telescope* Quasar Absorption Line (QAL) Key Project (Savage 1993, AJ, 413, 116) and Goddard High Resolution Spectrograph observations (Savage 1997, AJ, 113, 6). With our experiment, we will be able to directly compare the covering factors, scale heights, and kinematic, chemical, and ionization conditions of C IV, N V, and O VI, and the redistributions of these metals in the halo of the MW to observationally measured quantities. We will also constrain the underlying temperatures, density, and ionization structure of gas in the halo.

Connors et al (2006, ApJ, 646, L53), implemented a similar method using low-resolution (~5 Kpc) simulations of two different MW-sized disk galaxies, concluding that HVCs are a natural occurence around MW-like galaxies in a ΛCDM universe. Their experiment, however, lacks the effect of shocks between HVCs and the MW halo - an effect we have the resolution to constrain.

Unique also to this approach is that I can examine how the gas in the MW evolved into its present state by performing this QAL experiment through higher redshifts (up to $z = 4$). This will probe the MW's evolution back in time through to when the Universe was 10% of its current age. The goal is to provide constraints on, and describe the evolution of, galaxies that are similar to our own Milky Way.

Several big questions about the MW and galaxy evolution remain: what are the distances to HVCs? Are they gravitationally bound to the MW? How does metal enrichment contribute to the scale heights and the distribution of gas in the halo? How does the processing of gas via the "galactic fountain" interact with the local environment? How did the galaxy we call home evolve to its current state? I can begin to answer these questions with my research.

Broader Impact: New Mexico (NM) is blessed with dark skies, even in the cities. On a clear night, anyone can visibly see the galaxy they call home. I will use the evolution of the Milky Way to engage junior high and elementary school students in southern NM, promoting participation in science. I have a unique opportunity to make an impact on, and learn from, underrepresented groups here, as over 45% of the population is Hispanic. I will set up a program to visit one classroom per month to emphasize the attainability of science and astronomy in each of their lives, motivating their personal portal to the Universe via the night sky. I will represent a female role model to encourage young women and minorities to pursue higher education, in particular careers in science.