Gas Flows in Galaxies: The Essential Role of UV Spectroscopy

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Sensitive, high-resolution UV spectroscopy must be an essential component of any future UV/optical astrophysics mission. The space ultraviolet (< 3100 Å) and particularly the FUV region around Lyα (1000-1500 Å) cover a dense forest of atomic and molecular transitions that probe temperatures from 10 K to > 1 million K and from circumstellar (~ 1 cm^{-3}) to intergalactic densities (~10^{-6} cm^{-3}). These are some of the most important physical diagnostics anywhere in the EM spectrum; some are entirely unique to the UV.

Galactic accretion and feedback are critical influences on galaxy properties and their evolution. Since its installation in 2009 the Cosmic Origins Spectrograph (COS) has demonstrated the power of UV spectroscopy to reveal these gas flows. We now know that the circumgalactic medium (CGM) is massive compared with galactic stellar populations (Werk+2013), that it contains almost half the metals that galaxies near L* have produced (Tumlinson+2011), that it harbors a large budget of nearly pristine gas accreting to form new stars (Lehner+2013), that it is influenced by galactic feedback from starbursts and AGN, which can transform its content or even remove it from the halo entirely (Borthakur+2013, Tripp+2011), and that it harbors a significant mass of baryons even in galaxies that have been quenched and remain passive (Thom+2012). These are significant new insights, but they are still based on aggregating single sightlines passing near relatively small samples of typical galaxies (N ~ 1 - 50), not on detailed mapping of individual galaxy halos across a wide range of galaxy mass and evolutionary state. Though there are still advances for Hubble left to make, many more great leaps await the next generation of UV spectroscopic capability. Apertures of 8+ m with improved detectors and optical coatings could achieve ~50-150x gains in total throughput over HST's current instruments. A next-generation spectrograph could observe sources 10x fainter than COS with spectral resolution several times higher (~3 km s^{-1}, resolving all but the narrowest cold gas lines). These two leaps together would lead us into two relatively unexplored discovery spaces:

(1) A mission extending the reach of the space UV to the "Lyman Ultraviolet" (Tumlinson, arXiv:1209.3272) would enable high-precision surveys of low-*z* galaxies with up to 20 sightlines per halo for a large number of galaxies within 50 Mpc. COS can reach 2 sightlines for very few galaxies and > 2 for M31 only.

(2) A new mission with 10x the reach of COS could survey the halos of 1000-3000 galaxies at z = 0.5-1.5, the epoch when the red sequence built up substantially and galactic star formation rates were 10x higher than today.

A new mission in the coming decades could find out:

1) *How star formation is quenched in galaxies* by star-formation and/or AGN-driven winds pushing gas into the CGM and beyond.
2) *Why red-and-dead galaxies stay that way* when their halos contain a lot of cold gas.
3) *How much baryonic mass exists in galaxy halos at ~1 million K*, a very poorly constrained portion of the galactic baryons budget.
4) *How far from galaxies metals can spread*, to directly constrain ejective feedback that everybody models but no one understands.
5) *How hot and cold gas, accretion and feedback, and metals are distributed* spatially through the CGM during all the major phases of galaxy evolution.