N93-26878

A Systematic Investigation of Edge-On Starburst Galaxies: Evidence for Supernova-Driven Superwinds

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The global wind generated by the collective effect of multiple supernovae and stellar winds from OB associations is a well developed concept both observationally and theoretically (e.g., McCray & Kafatos 1987). On a much larger scale, a starburst, the rapid (<few x 10^8 yrs) formation of many OB associations in a small volume (r<few kpc), with their accompanying stellar winds and high supernovae rate (3 SNe per 10 years in M82, Rieke et al. 1980), should result in a much larger and more vigorous supernova-driven wind, a superwind. Superwinds, while studied theoretically by many authors (e.g., Tomisaka & Ikeuchi 1988; Chevalier & Clegg 1985) and hence is on sound theoretical footing – have only recently been observed (e.g., Heckman, Armus, & Miley 1991). However, most observations are of a few of the nearest starburst galaxies. While these observations provide tremendous insight, we do not as yet understand the global and cosmological significance of galactic superwinds. In order to achieve this depth of understanding, we need to systematize our understanding, that is, we need to determine how prevalent superwinds are and how their properties depend on the star-formation rate and the properties of the galaxies that drive them.

Obtaining such depth in our understanding of superwinds has important consequencies both observationally and theoretically, not only for understanding the properties of starburst galaxies, but indeed, to gain new insight into some of the most outstanding problems of astrophysics. Galactic winds have often been hypothesized to: 1) enrich and heat the inter-galactic medium in clusters, 2) play a critical role in the Hubble Sequence by sweeping cold gas out of proto-bulges/ellipticals, 3) help determine both the mass/metallicity relation between galaxies and the metallicity/radius relation within galaxies, 4) explain some classes of QSO absorption lines, 5) blow away dust and gas in Far-IR Galaxies, possibly facilitating their evolution into optical QSOs, and 6) stimulate the formation of galaxies in the IGM surrounding a newly-formed galaxy and so play a role in the formation of structure in the universe.

We are completing a project designed to realistically assess the global/cosmological significance of superwinds by attempting to systematize our understanding of them (determine their incidence rate and the dependence of their properties on the star-formation that drives them). Specifically, we are analyzing data from an optical spectroscopic and narrow-band imaging survey of an infrared flux-limited sample of about 50 starburst galaxies whose stellar disks are viewed nearly edge-on. This edge-on orientation is crucial because the relevant properties of the superwind can be far more easily measured when the flow is seen in isolation against the sky rather than projected onto the much brighter gas associated with the starburst galaxy itself. These galaxies are all IR "warm" ($S_{60\mu m}/S_{100\mu m}$ >0.4) and have IR luminosities from $\approx 10^9 - 10^{12} L_\odot$ and allow us to discern the properties of galactic superwinds as a function of IR luminosity and hence the star-formation rate. We show that extra-planar emission-line gas is a very common feature of these edge-on galaxies and the properties of the extended emission-line gas (radial pressure profiles that fall as approximately r^{-2}, line ratios becoming more shock/AGN-like as one proceeds out along the minor axis, filamentary and shell-like emission-line morphologies, optical emission-line widths that depend more strongly on the infrared luminosity than on the disk rotation amplitude, etc.) are quantitatively consistent with the superwind theory.