FUSE & XMM Observations of VV114: Feedback in a local Lyman Break Analogue

JOHNS HOPKINS UNIVERSITY

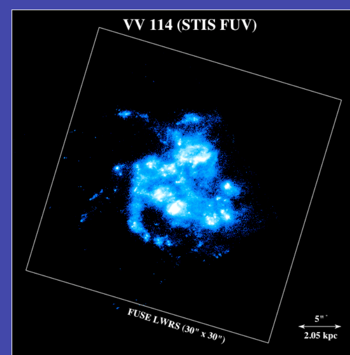
John Grimes, Timothy Heckman, Charles Hoopes, Dave Strickland

Introduction

In galaxies undergoing intense star formation, outflows powered by supernovae and stellar winds expel metal enriched material and ionizing radiation into the ISM and even beyond, into the IGM. The higher star formation rates at earlier epochs imply that galactic outflows are even more prevalent in high redshift star forming galaxies such as the well studied Lyman Break Galaxies (LBGs). These complicated multi-phase winds provide a continual feedback mechanism between galaxy formation and star formation.

NICMOS False Color Image of VV 114

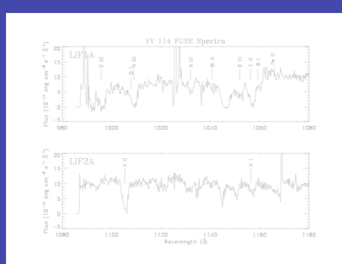
HST NICMOST & STIS data courtesy of Gerhardt Meurer



VV114 & LBGs

Understanding the effects of winds in LBGs then is an essential step in understanding how star formation affects later galaxy formation. In the FUV, absorption line studies can examine the velocity, composition, and phase of the cool material being accelerated by the winds. X-ray observations trace the hot gas from the collision of the high speed outflow with the cool, ambient ISM material. Unfortunately, LBGs are currently unobservable in the FUV & X-ray. Therefore we must observe local, similar galaxies to LBGs to extend our knowledge of LBGs into these wavelengths.

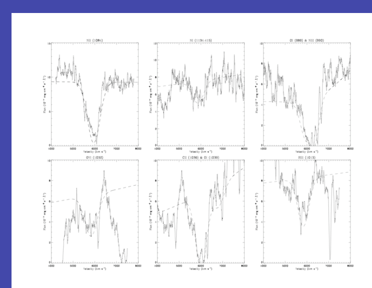
The interacting/merging galaxy VV 114 has been identified through SDSS and GALEX observations as a local LBG analogue (Heckman et al. 2005). VV 114 is similar to LBGs in L_{UV}, UV surface brightness, SFR, galaxy size, and galaxy mass. Although there are two components to the galaxy, only the western component is visible due to heavy dust absorption of the eastern component. CO maps of the system (Yun et al. 1994) show extended molecular gas centered between the two components. The gas coincident with the UV visible western component is moving at speeds between 5960 km/s to 6160km/s.



This plot shows two channels of the FUSE spectra of VV 114.

FUSE Spectra of VV114

The FUSE spectra shows many strong, **blueshifted** ISM absorption lines. The centroids of the lines range from -50 to -200 km/s relative to the molecular gas. Their FWHMs (~600 km/s) are similar to those seen in LBGs such as CB 58 (Pettini et al. 2002). There are also striking similarities between several of the absorption line profiles with detectable common features at ~5550, 6130, & 6270 km/s.

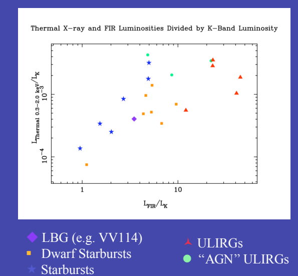


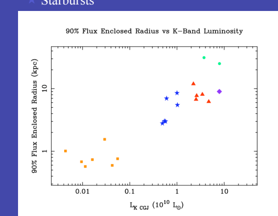
Blowup of several of the more prominent absorption lines.

X-ray Observations

An optically thin, thermalized gas model (vmekal) was fit to the X-ray spectra. We found an emission weighted temperature of 0.59 keV. An enrichment of the α-elements was also found with an α/Fe ratio of ~2.2. This would be expected in a wind driven by SN II ejecta. Both the gas temperature and α/Fe enhancement are typical of local starburst galaxies (Grimes et al. 2005).

We have also compared the X-ray, K-band, and FIR properties of VV114 to a sample of local star forming galaxies which included dwarf starbursts, starbursts, and ULIRGs. VV 114 (purple diamond) follows the same relationship between FIR emission and thermal X-ray emission (suggesting a near constant efficiency in turning kinetic energy from the winds into X-ray emission). The scale of the X-ray emission is also well correlated with the FIR & K-Band (a proxy for stellar mass) luminosities.





Conclusions

- VV 114 has strong, blueshifted absorption lines that appear to be similar in equivalent width and velocity dispersion to those seen in LBGs.
- The X-ray properties of VV114 are almost identical to those of ULIRGs, however the ULIRGs have slightly higher L_{FIR}/L_K ratios and dust temperatures (as measured by F_{60}/F_{100}).
- VV114 appears to be an excellent local laboratory for studying properties of high redshift LBGs.

Future work will require higher quality X-ray data of VV114 (this is a Chandra Cycle 7 target).