Abstract

We present evidence for outflows in (U)LIRGs by the occurrence of P Cygni profiles in their spectra. We estimate outflow velocities by measuring the velocity shifts in the emission and absorption components. We find no correlation of outflow velocity with infrared luminosity within the errors. We also show near-linear correlation of transition luminosities of OH⁺ and H₂O⁺ with infrared luminosity.

Sample

We use the HerCULES sample of (U)LIRGs. The Herschel Comprehensive (U)LIRG Emission Survey is an Open Time Key Program (PI: van der Werf) using SPIRE aboard the Herschel Space Observatory. It consists of ~40 (U)LIRGs. We measure velocities and line fluxes using FTFitter.

Water-like molecules like H₂O, OH⁺, and H₂O⁺ show P Cygni profiles. These •0,0H⁺, and H₂O+ IN/ molecules have both an emission and absorption component. Outflows cause the emission (absorption) peak to be red- (blue-) shifted resulting in velocity shifts of the peaks relative to the system velocity. The velocity difference between the emission and the absorption peak is a measure for the outflow velocity. We look for P Cygni profiles for these molecules and investigate their properties. We perform a principal component analysis to find correlations between sources and their properties. In the top panel are the sources. Dark colours are starburst dominated, while the lighter the colour, the more AGN-dominated the source. Similar colours are grouped together, indicating that AGN/ SB-domination is an important factor. This can also be seen in the bottom panel where the galaxy properties are shown. EW — the equivalent width of the 6.2 μ m PAH feature — is a proxy for AGN/SB domination, and is largely responsible for the variation in PC1. As expected it is anti-correlated with infrared luminosity. H_2O — the total luminosity in H_2O over infrared luminosity — is correlat-

ed with LIR and anti-correlated with EW, indicating that the IR brighter and more AGN-dominated a source, the more H₂O it contains.



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●EW ●O[I] + C[II]

Profiles and shifts

We present examples of P Cygni profiles, indicative of the presence of outflows, in our sample. In the upper panels, part of the spectrum is show, with the P Cygni profile indicated in red. In the bottom panels we plot this 'outflow velocity' as a function of infrared luminosity for the P Cygni profiles of the upper panels. Outflows are present (v > 0 km/s), however within the errors there is no indication of an evolution with infrared luminosity.



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Future work

- We want to find the location and properties of the OH+/H₂O+ emitting medium.
- Understand the role, if any, of radiative excitation.
- To achieve a fuller understanding of the physical processes occurring in (U)LIRGs, we will model the spectra using radiative transfer codes and PDR/XDR codes.
- We will investigate the nature of (U)LIRGs at high redshifts using ALMA spectra. We can then make a comparison with (U)LIRGs in the local universe.

