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Herschel spectroscopic observations of Zw 049.057 and Arp 299a

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Abstract. The presence of compact obscured nuclei in luminous infrared galaxies (LIRGs) is very well probed by the detection of highly excited absorption lines of OH and H_2O in the far-infrared (far-IR), which require warm and optically thick dust to pump the high-lying rotational levels. We are using a spherically symmetric radiative transfer code to model the H_2O lines, OH lines and continuum from these objects. We discuss the results and analysis of Herschel observations of the compact obscured nucleus in the extremely H_2O luminous LIRG Zw 049.057. In this galaxy we have found very high H_2O abundances in a Compton thick compact core. Abundant ^{18}O bearing species also suggest the presence of a relatively young starburst. We compare this to our observations and modeling of the luminous merger component Arp 299a, which is another source with prominent H_2O and OH lines. Our preliminary results, however, suggest that its nuclear activity is in a different evolutionary state compared to Zw 049.057.

Keywords. ISM: molecules – Galaxies: ISM – Line: formation – Infrared: galaxies

1. Introduction

Luminous infrared galaxies (LIRGs) are extreme examples of star-forming galaxies or galaxies with active galactic nuclei (AGN), often interacting or merging systems, whose high infrared luminosities are powered by intense star formation or AGN activity. There is mounting evidence that some LIRGs host extremely compact obscured nuclei (CONs) that are Compton thick with extreme H_2 column densities ($N_{H_2} > 10^{24}$ cm^{-2}) (e.g. Aalto *et al.*2012; Costagliola & Aalto 2010; Costagliola *et al.*2013; González-Alfonso *et al.*2015; Sakamoto *et al.*2013). Through studying molecular species that are mainly excited by warm dust emission (e.g. OH, H_2O) it is possible to probe the nuclear source of far-IR radiation in these objects and gain insights in its physical conditions and chemistry.

Here we discuss the results of Herschel observations of the CON Zw 049.057 and compare them to preliminary results of observations of the merger Arp 299a.

2. Observations and models

Both galaxies have been observed with the PACS and SPIRE instruments on Herschel. We used the spherically symmetric radiative transfer code described in González-Alfonso & Cernicharo (1997, 1999) to simultaneously model the dust continuum and H_2O lines in both galaxies. The model for Zw 049.057 (Falstad *et al.*2015) consists of two components. A Compton-thick and warm ($T_{dust} > 100$ K) core with high columns of H_2O and a low $^{16}O/^{18}O$ ratio (~ 50) is responsible for most high-lying absorptions while the submm emission lines form in a component with lower T_{dust} (~ 50 K) and H_2 columns. Signs of in- and outflowing gas are present in spectra of [O I] 63 μm and H_2O $3_{13} \rightarrow 2_{02}$.

Preliminary results for Arp 299a (Fig. 1) suggest that its high-lying absorption lines are also formed in a warm ($T_{dust} > 90$ K) core with a large column of H_2 ($> 10^{24}$ cm^{-2}). Like in Zw 049.057 the submm emission lines seem to originate in a more extended region with lower

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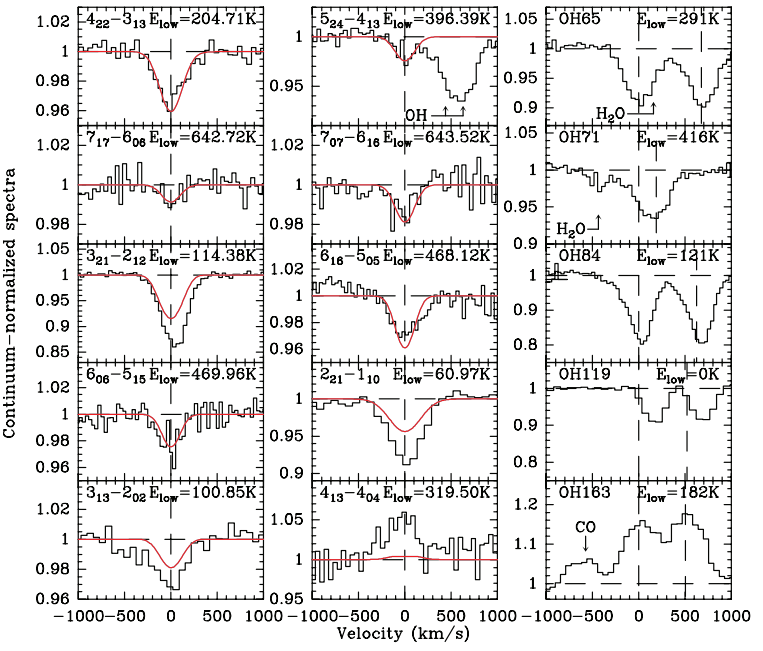

Figure 1. H_2O and OH in Arp 299a, including a preliminary model for the highest H_2O lines.

H_2 column density, the dust temperature in this region is likely to be slightly lower than in the core. Unlike in Zw 049.057, no ^{18}O species are detected with PACS.

3. Conclusions

The most important conclusions stemming from the observations and modeling are:

- In Zw 049.057 (Falstad *et al.*2015):
  - High H_2 column, up to 10^{25} cm^{-2} – a Compton thick nucleus.
  - Very high water abundance, $\sim 10^{-6}$, and signs of both infall and outflow, suggesting rapid evolution.
  - Enrichment of ^{18}O with an $^{16}O/^{18}O$ ratio of ~ 50.
- In Arp 299a (preliminary):
  - High H_2 column density towards the core, but not as extreme as in Zw 049.057.
  - No evidence of enhanced ^{18}O abundances – different starburst stage than Zw 049.057?

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