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A Survey of Spectral Features in ISO SWS Spectra of AGNs

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1. Introduction

Various AGNs, starburst galaxies, and ultraluminous infrared galaxies (ULIRGs) are observed as part of the *ISO*-SWS central program of mid-infrared spectroscopy on bright galactic nuclei. Prototypical template sources are scanned over the full spectral range of SWS (2.5–45 μm) in order to get a complete census of spectral features in this wavelength domain. As an example we present the spectrum of the Seyfert 2 galaxy Circinus. The application of results from this survey to the study of the nature and evolution of other galaxies can be demonstrated by an analysis of the ultraluminous infrared galaxy Arp 220.

2. Circinus Galaxy

The Circinus galaxy (A1409−65), a survey-program template, exhibits both a visually obscured Seyfert nucleus and circumnuclear starburst activity. A complete spectrum (Fig. 1) has been observed in the *ISO*-SWS full grating scan mode (AOT SWS01). Jumps in the flux density, e.g., $\sim$ 29 μm are caused by changes in the aperture size and also by remaining uncertainties in the flux calibration of order 20–30%. The spectrum contains contributions from several sources: between 5–12 μm, PAH features dominate the emission. They closely resemble spectra of pure starburst galaxies observed with *ISO*. Several rotational lines of H_2 as well as low-excitation fine-structure lines like [Ar II] 7μm, [Fe II] 26μm, [Ne II] 12.8μm, or [S III] 19 and 33μm can be predominantly ascribed to the starburst region. Intermediate-excitation lines like [Ar III] 9μm, [S IV] 10.5μm, and [Ne III] 15.6μm most probably arise from both the starburst and the AGN. High-excitation lines like [Ne V] 14 and 24μm, [Ne VI] 7.6μm, [O IV] 26μm, [Mg VIII] 3μm, or [Si IX] 3.9μm, require much harder radiation fields than can be produced in a starburst and clearly arise in gas photoionized by the AGN.

3. Arp 220

The demonstration that high-excitation lines can be observed in the mid-infrared spectra of AGNs and that they can be used to distinguish between contributions from starbursts and AGNs provides an important tool to study the nature of the enigmatic ultraluminous galaxies. One of the most prominent representatives of this class of galaxies is Arp 220. Due to the high level of extinction it

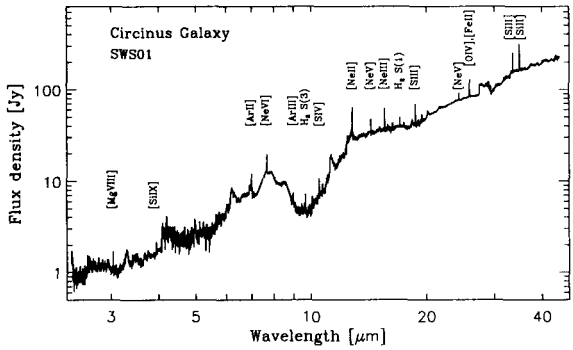

Figure 1. Complete SWS01 spectrum of the Circinus galaxy.

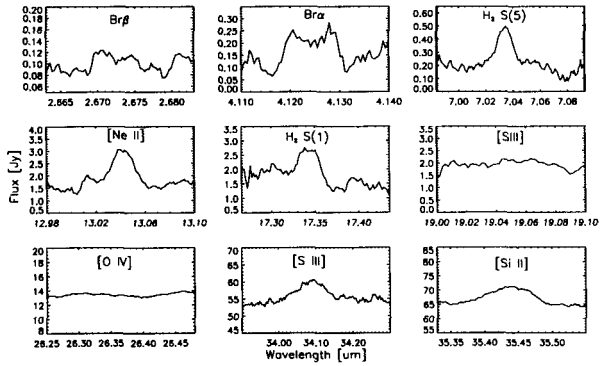

Figure 2. Individual SWS02 line scans of Arp 220.

was up to now not clear which energy source, a hidden AGN or a very efficient starburst, is responsible for the extreme infrared luminosity. *ISO*-SWS observations of mid-infrared lines penetrate for the first time deep enough into the highly obscured regions where the luminosity originates. A subset of the spectra, taken in the spectral line scanning mode (AOT SWS02), is shown in Fig. 2. For many lines, like [S III] 19μm and [O IV] 26μm, only upper limits can be derived. From the line ratios of the Brackett lines and from the upper limit of the ratio [S III] 19μm/[S III] 33μm, we derive a mean extinction of $A_V = 50 \pm 10$ mag. This is significantly higher than the values that have been assumed in most past studies. High-excitation lines like [O IV], [Ne V], indicators of AGN activity, could not be detected. This can not be due to the high extinction alone, because the extinction-corrected 3σ upper limits on the diagnostic line ratios of [O IV]/[Ne II] and [Ne V]/[Ne II] are significantly below the corresponding values found in *ISO* spectra of typical AGNs like Circinus. On the other hand the value of $L_{Bol}/L_{Lyc} \approx 20$, derived from the [Ne II] luminosity taking into account the high level of extinction, can be fit by starburst models. This is evidence that Arp 220 is primarily powered by star formation.

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