Mid-Infrared Spectral Indicators of Star-Formation and AGN Activity in Normal Galaxies

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Abstract. We investigate the use of mid-infrared PAH bands, continuum and emission lines as probes of star-formation and AGN activity in a sample of 100 'normal' and local (z ∼ 0.1) galaxies. The MIR spectra were obtained with the Spitzer IRS as part of the Spitzer-SDSS-GALEX Spectroscopic Survey (SSGSS) which includes multi-wavelength photometry from the UV to the FIR and optical spectroscopy. The spectra were decomposed using PAHFIT (Smith et al. 2007), which we find to yield PAH equivalent widths (EW) up to ∼ 30 times larger than the commonly used spline methods. Based on correlations between PAH, continuum and emission line properties and optically derived physical properties (gas phase metallicity, radiation field hardness), we revisit the diagnostic diagram relating PAH EWs and [Ne ii]12.8µm/[O iv]25.9µm and find it more efficient as distinguishing weak AGNs from star-forming galaxies than when spline decompositions are used. The luminosity of individual MIR component (PAH, continuum, Ne and H₂ lines) are found to be tightly correlated to the total IR luminosity and can be used to estimate dust attenuation in the UV and in Hα lines based on energy balance arguments.

1 Goals

We aim at determining the main source of ionizing radiation and star-formation rate of normal galaxies from MIR spectroscopy.

2 The SSGSS Sample

The Spitzer-SDSS-GALEX Spectroscopic Survey is an IRS survey of 100 local galaxies in the Lockman Hole. The data include GALEX FUV photometry, SDSS optical imaging and spectroscopy, Spitzer IRAC and MIPS photometry. The sample has a surface brightness limit of 0.75 MJy sr⁻¹ at 5.8µm and a flux limit of 1.5mJy at 24µm. It was selected to cover the range of physical properties...
of ‘normal’ galaxies (e.g. $9.3 \leq \log(M/M_\odot) \leq 11.3$, $8.7 \leq \log(O/H) + 12 \leq 9.2$, $0.4 < A_{H\alpha} < 2.3$). The redshifts span $0.03 < z < 0.21$ with a mean of 0.1 similar to that of the full SDSS spectroscopic sample. Galaxies are classified as star-forming (black dots), composite (pink stars) or AGN (red triangles) according to the boundaries of Kewley et al. (2001) and Kauffmann et al. (2003) on the [N ii]$\lambda 6583$/H$\alpha$ versus $\delta$3hb “BPT” diagram (Baldwin et al. 1981). First results were reported by O’Dowd et al. (2009).

3 Spectral Decomposition

We used PAHFIT (Smith et al. 2007) to decompose the spectra into a sum of dust attenuated thermal dust continuum, PAH features and emission lines. The left panel of Fig. 1 shows an example decomposition for a typical SF galaxy. The right panel shows the mean spectra of SF galaxies, composite galaxies and AGNs along with the average starburst spectrum of Brandl et al. (2006). The transition from starburst to SF galaxy to AGN is marked by a declining continuum slope, decreased [Ne ii]$12.8\mu$m and [S iii]$18.7\mu$m emission and enhanced [O iv]$25.9\mu$m emission. The AGN spectrum, and to a lesser extent the starburst spectrum, show weaker PAH emission at low wavelength than the SF spectrum, an effect attributed to the destruction of PAHs in intense far-UV radiation fields.
MIR indicators of SF and AGN in Normal Galaxies

4 Conclusions

- We find systematic trends between MIR spectral properties and optically derived physical properties, in particular between short wavelength PAH EWs and [N II]6583/Hα (gas phase metallicity), and between [Ne II]12.8µm/[O IV]25.9µm versus ϕ3hb (radiation field hardness) (Fig. 2, left panel);
- The Genzel et al. (1998) diagram has better resolution using PAHFIT than spline decompositions. It is very similar to the optical “BPT” diagram (Fig. 2, right panel). The mixed SF/composite region may be revealing obscured AGNs in a large fraction of optically defined “pure” SF galaxies.
- The PAH, continuum, Ne and H2 luminosities are tightly and nearly linearly correlated to the total IR luminosity, less so to the dust corrected Hα luminosity (SFR) (Fig. 3, left panel);
- Following Kennicutt et al. (2009), the MIR components can be used to estimate dust attenuation in Hα and UV based on energy balance arguments (Fig. 3, right panel).

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Treyer et al.

Figure 3. **Column 1:** $L_{\text{MIR}}/L_{\text{TIR}}$ ratios as a function of $L_{\text{TIR}}$ where $L_{\text{MIR}}$ equals - from top to bottom - the $24\mu m$ MIPS band luminosity ($\nu L_\nu$), the luminosity of the $7.7\mu m$ PAH complex and the $H_2$ luminosity where $H_2$ is defined as the sum of the $S(0)$ to $S(2)$ rotational lines. The logarithmic scaling factors $\kappa$ are defined as the mean of $\log(L_{\text{TIR}}/L_{\text{MIR}})$ for the SF population alone (green dashed lines). The rms and Pearson coefficient $r$ are also for the SF population alone. **Column 2:** $L_{\text{MIR}}/L_{\text{corr}H_\alpha}$ ratios as a function of $L_{\text{corr}H_\alpha}$ (the dust corrected H$\alpha$ luminosity). **Column 3:** $L_{\text{MIR}}/L_{\text{obs}H_\alpha}$ ratios (observed H$\alpha$ luminosity) against H$\alpha$ attenuation measured from the Balmer decrement. The solid lines are best fits to $A_{H_\alpha} = 2.5 \log \left[1 + a_{\text{MIR}} L_{\text{MIR}}/L_{\text{obs}H_\alpha}\right]$ (Kennicutt et al. 2009). **Column 4:** $L_{\text{obs}H_\alpha} + a_{\text{MIR}} L_{\text{MIR}}$ to $L_{\text{corr}H_\alpha}$ ratios as a function of $L_{\text{corr}H_\alpha}$. The $a_{\text{MIR}}$ coefficients derived in the previous column are indicated at the top left of each panel.

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