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# X-RAY HARDNESS RATIO AND MID-INFRARED PARAMETERS FOR AGNS

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**Abstract.** We use the resulting parameters of the two different model decompositions of mid-infrared (MIR) spectra of 1) active and star-forming galaxies and 2) active galactic nuclei (AGN). These resulting parameters are the AGN, polycyclic aromatic hydrocarbons – PAH, H II and stellar contribution components, silicate contribution, etc. It is found that some of these parameters correlate with X-ray hardness ratios (especially *HR1*). This reveals the insight in the X-ray energy bands that influence the MIR parameters and it can point to the AGN sources that are more obscured. These correlations indicate the high attenuation of soft X-ray radiation by the dust.

## 1. INTRODUCTION

Studying correlations between X-ray and mid-inrared (MIR) spectral parameters for active galactic nuclei (AGNs) is crucial for our understanding of a wide range of astrophysical phenomena, from the physics and properties of individual objects to the broader cosmological context. X-rays are emitted from the hot, inner regions close to the black hole; soft X-rays (<10eV) are often associated with thermal processes, such as thermal bremsstrahlung emission from hot plasma or blackbody radiation from accretion disks around compact objects like black holes or neutron stars. The hardness ratios (HRs) are often used as a tool for classifying different types of AGNs, and as indicators for the attenuation: higher absorption tends to attenuate soft X-rays more strongly than hard X-rays, resulting in a harder spectrum. MIR emission often originates from the dusty torus, or from the host galaxy. MIR parameters are often used to estimate the star formation, nuclear activity, or the amount of AGN obscuration (Hernán-Caballero & Hatziminaoglou 2011, here H11). In this work we will compare silicate features as well as AGN contribution to MIR spectra obtained on the two different methods with X-ray HRs.

## 2. DATA AND METHODS

X-ray survey (*4XMM-DR13* – from the catalogue Webb et al. 2020[1]) contains data for 550.124 unique sources, in following bands: Flux1: 0.2–0.5keV band, Flux2: 0.5–1.0keV, Flux3: 1.0–2.0keV, Flux4: 2–4.5keV, Flux5: 4.5–12keV, Flux8: 0.2–12keV and Flux9: 0.5–4.5keV. From these fluxes, they calculate HRs ratios using formula

[1]http://xmmssc.irap.omp.eu/Catalogue/4XMM-DR13/4XMM_DR13.html

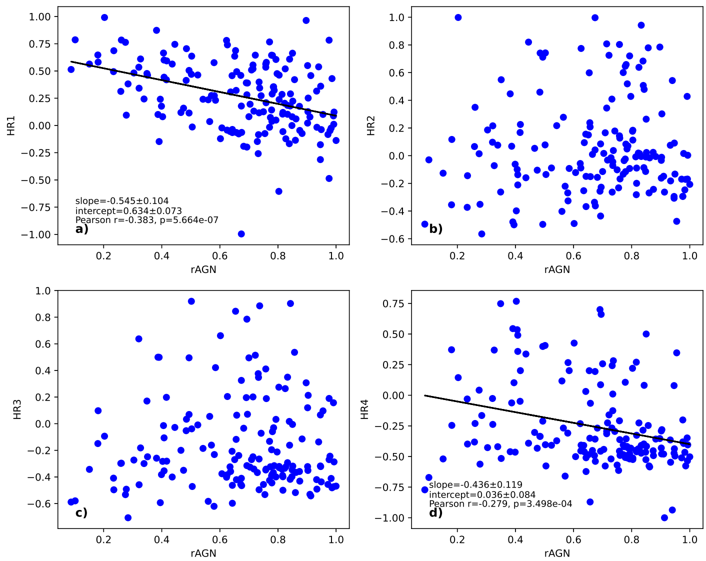


Figure 1: Dependence of AGN fraction in MIR spectra of the four hardness ratios (first dataset, from H11).

$HR_{1,2}$=($F2$−$F1$)/($F2$+$F1$), where adopted *HR1*=$HR_{1,2}$, *HR2*=$HR_{2,3}$, *HR3*=$HR_{3,4}$ and *HR4*=$HR_{4,5}$.

We used the results of the two different decomposition analysis of MIR AGN *Spitzer IRS* spectra from the works of H11 and Hernán-Caballero et al. 2015 – here H15. The H11 dataset contains measurements of the strength of the silicates in emission/absorption (*Sil*), and decomposition of spectra to HII, Photodissociation Regions (PDRs) and AGN contributions, rAGN, rHII and rPDR for 739 star-forming and active galaxies. rPDR is measurement of PAHs in galaxies. *Sil* is well correlated with optical depth. The H15 dataset contains spectral decomposition of 118 spectra of local AGNs. Similarly as in the first decomposition, the results are measurements of *Sil*, rAGN, rPAH and rSTR (AGN, PAHs and stellar contributions).

The objects from the two MIR datasets (H11 and H15) were crossmatched with X-ray data and 176 sources are obtained for the first, and 98 objects for the second crosmatch, respectively.

## 3. RESULTS

As we can see in the Fig. 1, for H11 dataset: rAGN depends significantly on the *HR1*, although there is slight dependence on *HR4*, too. Likewise, we found the significant dependence of the *Sil* on the *HR1*, *HR3* and *HR4* (Fig. 2). Similar is for H15 dataset: rAGN depends on the *HR1*, while the correlations with other HRs are missing (Fig. 3). Here, *Sil* depends on the *HR1* and *HR4* (Fig. 4). In both samples *HR1* is mostly correlated with *Sil* and with rAGN parameter.

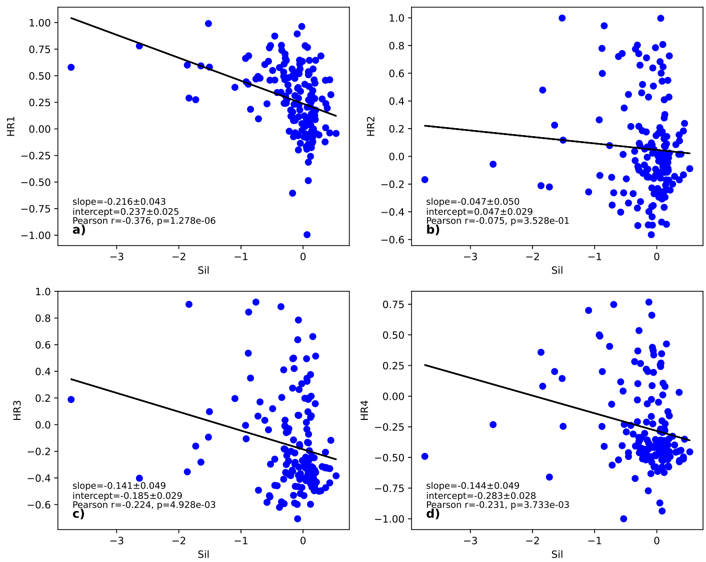


Figure 2: Dependence of silicate feature in MIR spectra of the four hardness ratios (first dataset, from H11).

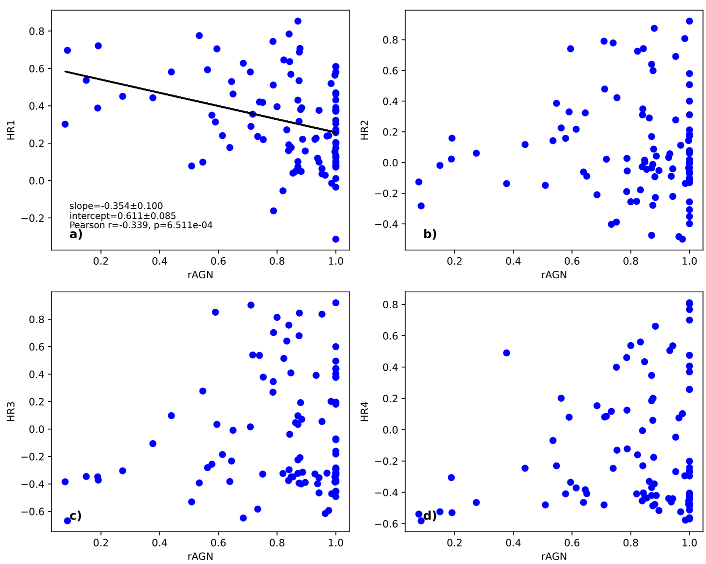


Figure 3: Dependence of AGN fraction in MIR spectra of the four hardness ratios (second dataset, from H15).

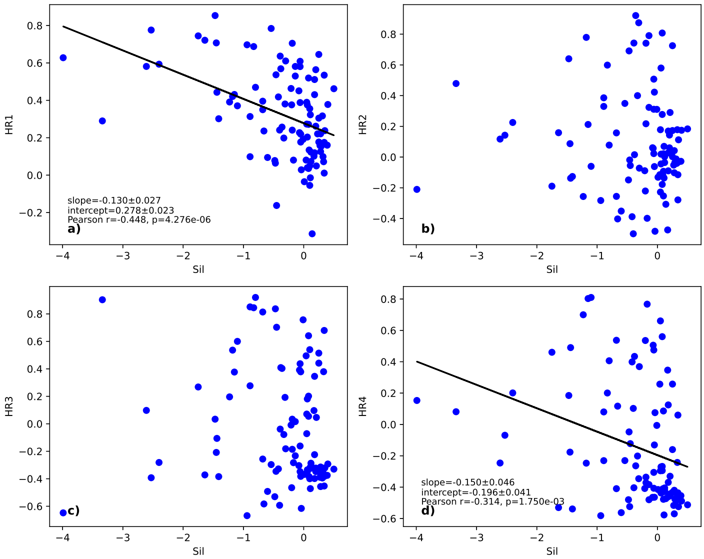


Figure 4: Dependence of silicate feature in MIR spectra of the four hardness ratios (second dataset, from H15).

## 4. SUMMARY

We explored the correlations of HRs with *Sil* and rAGN for the two different datasets. *HR1* is always correlated with both of those parameters, while *HR3* and *HR4* are sometimes correlated with *Sil* and/or rAGN. Therefore, *HR1* is the most connected with MIR spectroscopic parameters. The trend between rAGN and *HR1* can be explained by the dust attenuation: higher absorption tends to attenuate soft X-rays more strongly than hard X-rays, therefore objects with low AGN contribution have a harder spectra (larger *HR1*). *Sil-HR* trend that we noticed is the consequence of known fAGN-*Sil* relation (H15).

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[2] http://www.star.bris.ac.uk/mbt/topcat/