Emission and absorption in Narrow-Line Seyfert 1 Galaxies

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Abstract.
The emission and absorption attributes of the UV-blue nuclear spectra of the Narrow-Line Seyfert 1 (NLS1) galaxies are analyzed based on high quality archival HST observations. Measurements from composite spectra as well as from individual sources reveal differences from the more general AGN samples: NLS1s have steeper (redder) UV-blue continua. Objects with UV line absorption show redder spectra, suggesting that internal dust is important in modifying the continuum shapes. A strong relationship is found between the slopes of the power-laws that best fit the UV-blue continua and the luminosities: the more luminous sources have bluer SEDs. This trend is possibly attributed to a luminosity-dependent inner geometry of the obscuring (dusty) material.

1. Introduction
NLS1s are interesting objects due to their extreme continuum and emission-line properties. Their fame as peculiar AGNs is mostly built on analysis of either individual objects or, with the exception of X-ray observations, small samples. Detailed investigations of the NLS1 UV/blue spectral properties are particularly limited (e.g., Rodriguez-Pascual, Mas-Hesse & Santos-Lleo 1997, Kuraszkiewicz & Wilkes 2000); however, the mounting number of high-quality IIST spectra of these sources allows now for a better definition of their spectral properties in general, and of their UV emission in particular.

This project attempts a comprehensive UV-optical spectral characterization of the typical NLS1 galaxy. The emission and absorption characteristics of a sample of 22 NLS1-like objects are analyzed by employing measurements in both individual and composite spectra (see Constantin & Shields 2003 for details on the sample definition and data analysis).

Figure 1 shows the NLS1 composite spectra constructed with this (HST archival) NLS1 data. The power-law that best fits the UV-blue continuum in the NLS1 median composite has an index $\alpha = -0.79$ that falls among the steepest values found in other AGN composite measurements (e.g., $\alpha = -0.44$ in the SDSS sample, Vanden Berk et al. 2001, and $\alpha = -0.36$ for the LBQS sample, Francis et al. 1991). Understanding the origin of the NLS1 continuum redness is important as this may be related to the overall peculiar nature of these objects.
Figure 1. Top panel: NLS1 composite spectrum plotted as \( \log(F_\lambda) \) vs. rest-frame wavelength, with the principal emission features identified. The flux has been normalized to unit mean flux over the wavelength range 1430 Å–1470 Å. Middle panel: The broken power-law \( (F_\nu \propto \nu^\alpha) \) that best fits the continuum is overplotted on the median composite, which is plotted here on a linear scale and zoomed near the continuum level for a better visualization of the weak features. Bottom panel: Number of NLS1s contributing to the composite as a function of rest-frame wavelength. Only very few objects span the whole spectral range; the UV-blue wavelengths are however well represented by the sample.
2. What causes the redness of the NLS1s?

A first clue to what may trigger the relatively steep spectral slope in the NLS1 composite comes from the relation found between the spectral slope $\alpha$ and the luminosity (Figure 2, left panel): steeper slopes are measured in the lower luminosity sources. Since NLS1s have typically lower luminosities than those of the sources employed in most other quasar composites, the $\alpha - L$ correlation might explain the trend toward redder continua in these objects.

Independent evidence suggests further that the luminosity dependence of the spectral index is mostly attributable to a luminosity-dependent reddening. In almost half the objects in this sample, absorption near the systemic velocity of the host galaxy is present. Moreover, the spectral indices measured in the subsamples with and without UV resonance line-absorption are in median $-1.34$ and $-0.73$, respectively, suggesting that dust, which is expected to accompany the absorbing gas, plays an important role in modifying the continuum shape in these objects. The median logarithmic luminosities for the absorbed and unabsorbed subsamples are 29.01 and 29.60 respectively, thus directly linking the presence of absorption with luminosity.

How can dust shape the QSO/NLS1 continuum? A natural expectation is that the circumnuclear interstellar medium assumes a disk-like geometry with a luminosity-independent scale height, and a sublimation radius $R_s$ that scales with the intrinsic luminosity $L$ of the central source ($R_s \propto L^{1/2} \text{bolometric}$, a receding torus-type picture, Lawrence 1991). In this simple scenario, a sample of quasars with a random distribution of intrinsic bolometric luminosities, inclination angles, and power-law indices of their intrinsic SEDs, will display UV-blue spectral indices that correlate strongly with the observed (reddened) luminosity. Figure 2, right panel, illustrates the results of simulating such dust extinction in an ensemble of quasars; the torus properties (particle density $n_H$, torus height $h$, extinction law $R_\lambda$) are considered the same for all objects. It is thus apparent that this framework offers a plausible explanation for the observed $\alpha - L$ trend that is also present in other, more heterogeneous AGN samples. Interestingly, the resulting numbers of absorbed sources predicted by this model appear consistent with recent x-ray observations of the extragalactic point source population.

Analysis of soft X-ray data could further test the nature of the dusty absorber in these sources; a low ionization gas would produce strong absorption, and therefore flatter observed soft X-ray spectra, while a “warm” (high ionization) absorber would imply that steeper soft X-ray continua should be measured (e.g., Grupe et al. 1998). A comparison of the median values of the ROSAT spectral indices ($\Gamma = 1 - \alpha$) for the absorbed and unabsorbed objects shows however only a slight difference (3.4 and 3.1, respectively) suggesting that the absorbing material may possess a range of properties.

3. Conclusions

An analysis of all publicly available spectra of NLS1 galaxies in the HST archive is presented here in an attempt to determine the UV-blue spectral properties of these sources. It is found that the NLS1s have redder continua than that
Figure 2. **Left panel:** Spectral indices measured in the HST NLS1 sample plotted vs. 1450Å luminosity, with $L_\nu$ expressed in erg s$^{-1}$ Hz$^{-1}$. The Spearman rank coefficient and the probability of the correlation happening by chance are indicated. The error bars in both directions are smaller than the symbol size, and therefore not indicated. **Right panel:** UV-optical spectral indices plotted vs. $L_\nu$ (1450Å) luminosities calculated for a simulated ensemble of quasars; the $\alpha - L$ trend is recovered by simply employing a luminosity-dependent reddening by dust.

measured in other more general AGN samples. In this sample, the spectral slope correlates strongly with the luminosity indicating that the redness of the NLS1s is related to the low luminosity of these objects. Moreover, the apparent connection between the UV resonance absorption lines and luminosity suggests that the steep slopes measured in these source are due at least partially to reddening. Simple simulations show that a luminosity dependence of the solid angle covered by the dust (as seen by the central source) potentially explains the $\alpha - L$ trend. The ionization state of the absorbing material and its relationship to the accretion source remain however ambiguous.

**References**

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