1

The Frequency of Circumnuclear Starbursts in Seyfert Galaxies - Testing the Starburst-AGN connection

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Abstract

We obtained sub-arcsecond medium resolution near-infrared spectra of a sample of nearby bright Seyfert galaxies (8 Seyfert 1s, 11 Seyfert 2s) using the KeckII telescope. The stellar absorption lines present in the spectra were used in conjunction with population synthesis models to determine the age of the circumnuclear stellar population. Initial analysis of a sub-sample of the Seyfert galaxies has provided no evidence for a connection between the age of the circumnuclear stellar population and the Seyfert type. The derived ages for the circumnuclear stellar population are in the range of 10 Myr to < 0.5 Gyr assuming an instantaneous starburst (using the STARBURST99 models).

1.1 Introduction

The unified scheme proposed for Active Galactic Nuclei (AGN) consists of a central black hole (BH) which is surrounded by an obscuring torus. In this picture the difference between Seyfert 1 and Seyfert 2 galaxies mainly depends on the orientation of the BH+torus relative to the line-of-sight, and not on the (nuclear) properties of the host galaxies. Recent modifications to the initially simple picture include for example an additional molecular torus (Maiolino et al. 1995), and/or obscuring material in the plane of the galaxy (Malkan et al. 1998). In addition it has been suggested that massive circumnuclear star formation can provide enough obscuring material due to mass-loss during the supernova phase to mask a Seyfert type 1 nucleus as a type 2 nucleus (e.g Ohsuga & Umemura 1999, see also scenario proposed by Norman & Scoville 1988). In this scenario, the younger circumnuclear stellar populations would show a prevalence for type 2 AGN. Therefore a possible starburst-AGN connection would be essential for the evolution of the AGN from type 2 to type 1.

The nuclear stellar properties of Seyfert galaxies are of great interest, as it has been hypothesized for many years that there might be a connection between nuclear star formation and the AGN activity/evolution (e.g., Norman & Scoville 1988). However, the importance of circumnuclear starbursts in Seyfert galaxies is still under debate, and quite controversial: e.g., Oliva et al. (1999) find evidence for powerful starbursts in about half of their Seyfert 2 galaxies (from H and K band spectroscopy), whereas Ivanov et al. (2000) only see starbursts in a minority of their Seyfert 2 galaxies (based on the K band CO band head as an indicator). Both studies do not find evidence for powerful starbursts in Seyfert 1 galaxies. If there is indeed a difference in the circumnuclear stellar populations between type 1 and type 2 Seyfert galaxies, the simple unified scheme for Seyfert galaxies may need substantial revision.

High angular resolution observations in the near-infrared (NIR) of the nuclear region of active galaxies are well-suited to investigate this problem via a quantitative analysis of the contributions of the AGN and the stars to the nuclear NIR continuum. The NIR offers two advantages over the optical wavelength ranges: (1) the extinction affecting the stellar light is much smaller (about 1/10 in the K band compared to the V band) and (2) the overall stellar contribution to the continuum emission is larger due to the spectral energy distribution (SED) of the AGN and the stars (e.g. Barvainis 1989). This allows for a more detailed analysis of the properties of the stellar contribution to the nuclear light. The utilization of population synthesis (e.g. Origlia et al. 1999) and NIR spectral synthesis models (Schinnerer et al. 2000, 2001) allows one to determine the star formation history of the nuclear stellar component.

1.2 Near-infrared Spectroscopic and Imaging Data

1.2.1 Keck NIRSPEC Observations

Our sample of 19 nearby, bright Seyfert galaxies was observed in 2001 March and November using the near-infrared spectrograph NIRSPEC at the KeckII telescope atop Mauna Kea, Hawaii. We obtained medium resolution spectra ($R \sim 1500$) in the H and K band for all our targets. In addition short integration images in the J, H, and K band were taken at the same time using the slit acquisition camera of NIRSPEC. The data reduction was done using standard task in IRAF, and included flat-fielding, cosmic ray removal, as well as atmospheric calibration.

1.2.2 The Sample

In order to avoid biases toward or against AGNs with circumnuclear starbursts, we carefully selected our sample of 19 bright Seyfert galaxies based on the Hβ and [O III] λ5007Å line emission from the Whittle (1992) and the Ho et al. (1995) samples. Our selection criteria were similar to Heckman et al. (1995) and González Delgado et al. (2000) which fulfill: log F(Hβ) > -14 erg s^{-1} cm^{-2} and log F([O III]) > -13 erg s^{-1} cm^{-2}. To allow for high spatial resolution observations the velocity range was restricted to < 5000 km/s (with the typical seeing at Mauna Kea of 0.7" we achieved a spatial resolution of < 250 pc for our entire sample). This is sufficiently small to avoid dilution of the nuclear light due to circumnuclear starburst rings which have typical diameters of 0.5 - 1.5 kpc (e.g. Maoz et al. 1996).

1.3 Analysis

1.3.1 Near-infrared Spectra

Our NIRSPEC spectra exhibit a wealth of emission lines coming from $[FeII]$, $Br\gamma$, HeI and H_2. A large variation in the continuum slope indicates a varying contribution of the hot dust emission from the AGN itself. The appearance of the nuclear spectra in our Seyfert sample is quite diverse ranging from absence of stellar absorption lines to the presence of strong stellar absorption lines (see Fig. 1). No

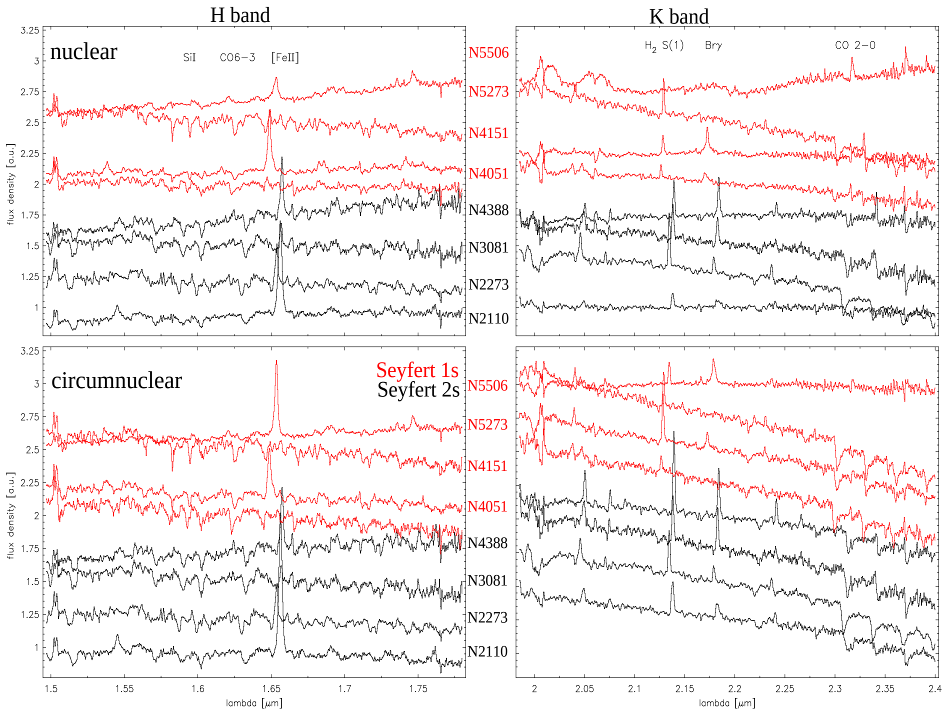

Fig. 1.1. Normalized NIRSPEC H (*left*) and K band (*right*) spectra of the nearest Seyfert galaxies in our sample. Both Seyfert 1s (*red*) and Seyfert 2s (*black*) show numerous emission lines as well as stellar absorption features (indicated in the top figures). The contribution of the AGN to the continuum is obvious in the nuclear spectra (r <63pc, *top*), whereas the stellar population is dominating the continuum in the circumnuclear region (75pc< r <150pc, *bottom*) for most of our sources.

preference for a Seyfert type and the presence of stellar absorption lines is obvious in our data. Due to the high quality of the data, rotation in the emission and absorption lines is observed in a number of sources.

1.3.2 Star Formation Diagnosis

The stellar contribution to the overall near-infrared luminosity can be quite significant, even very close to the AGN (e.g. the Seyfert 1.5 NGC 3227; Schinnerer et al. 2001). The stellar absorption lines of SiI and CO in the H and K band - arising in the atmospheres of red giants and supergiants - are well-studied (Origlia et al. 1999, Oliva et al. 1995), and allow to probe the interesting age range between a few million years and a few gigayears to test a possible starburst-AGN connection. The ratio of the H band lines ($SiI[1.58\mu m], CO\,6-3[1.62\mu m]$) is a good indicator for the effective temperature, and thus the mean spectral type of the dominating stellar population. Since the ratio is essentially unaffected by dilution, it allows us to estimate the stellar contribution to the observed H band luminosity. The dilution-

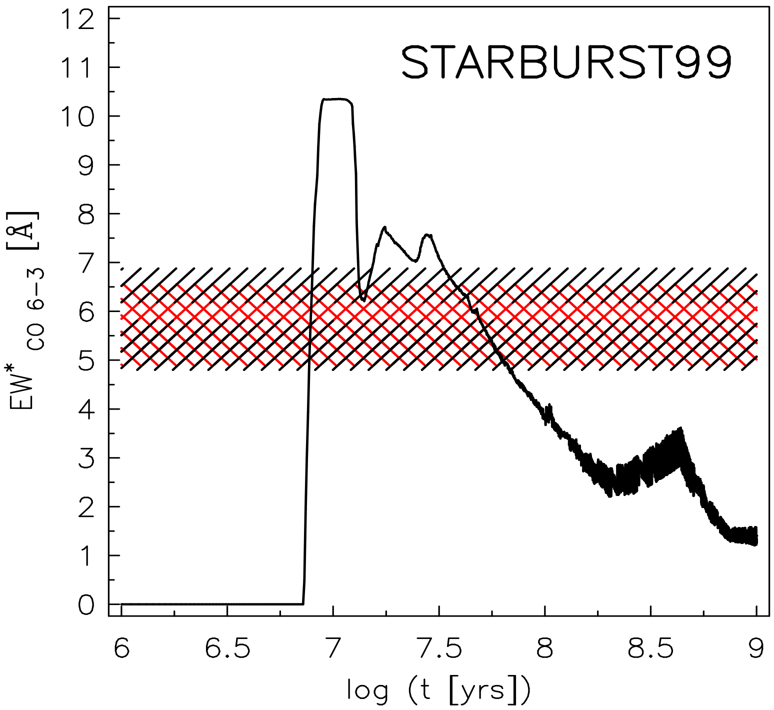

Fig. 1.2. The dilution corrected equivalent widths of the H band $CO\,6-3$ band head can be used as an age indicator. The dilution corrected equivalent widths for the sources shown in Fig.1 are indicated as hatched areas for the Seyfert 1s (*red*) and Seyfert 2s (*black*). As can be seen, both Seyfert types occupy a similar age range, as derived from the time evolution of the $CO\,6-3$ band head for a single 1 Myr starburst using the population synthesis program STARBURST99 (Leitherer et al. 1999).

corrected equivalent line width can be directly compared to predictions from stellar population synthesis codes, such as STARBURST99 (Leitherer et al. 1999) to derive an average age of the dominating stellar population in the circumnuclear region of a Seyfert galaxy.

1.4 First Results and Summary

Our preliminary analysis of medium resolution near-infrared spectroscopic data of the eight closest ($D \leq 40$ Mpc) Seyfert galaxies (4 Sy1, 4 Sy2) in our sample has shown that their circumnuclear spectra (75pc$< r <$ 150pc) are dominated by stellar absorption lines. The age of the circumnuclear stellar population was estimated via the H band line ratio of $CO6-3$ and SiI in conjunction with the observed equivalent width of the K band $CO2-0$ band head. Since the equivalent width of the SiI line does not vary with the stellar type (for late type stars), the ratio of the observed to expected equivalent width of SiI gives a good estimate of the stellar contribution to the H band continuum. For the sources analyzed, about 55% to 90% of the circumnuclear continuum is of stellar origin. We used these values to correct the equivalent widths of the H band $CO6-3$ band head for dilution effects, and compared these corrected equivalent widths to predictions from the population synthesis code STARBURST99 (Leitherer et al. 1999). The circumnuclear regions of our analyzed sources have stellar populations in the age range of 10 - 80 Myr assuming an instantaneous starburst scenario.

From our preliminary analysis, we find no significant difference in the age spread of the circumnuclear (75pc$< r <$ 150pc) stellar population in the Seyfert type 1's and 2's. This indicates that there might be no difference in the starburst properties of type 1's and 2's in agreement with the unified model. So far, our result suggests that there is no link between the type of an AGN and the age of the circumnuclear stellar population. Further analysis will include the full sample as well as spectral synthesis models.

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