STELLAR ABSORPTION LINES IN THE SPECTRA OF SEYFERT GALAXIES

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ABSTRACT

We have measured the strengths of Ca II triplet and Mgb stellar absorption lines in the nuclear and off-nuclear spectra of Seyfert galaxies. These features are diluted to varying degrees by continuum emission from the active nucleus and from young stars. Ca II triplet strengths can be enhanced if late-type supergiant stars dominate the near-IR light. Thus, objects with strong Ca II triplet and weak Mgb lines may be objects with strong bursts of star formation. We find that for most of our sample the line strengths are at least consistent with dilution of a normal galaxy spectrum by a power law continuum, in accord with the standard model for AGN. However, for several Seyferts in our sample, it appears that dilution by a power law continuum cannot simultaneously explain strong Ca II triplet and relatively weak Mgb. Also, these objects occupy the region of the IRAS color-color diagram characteristic of starburst galaxies. In these objects it appears that the optical to near-IR emission is dominated by late-type supergiants produced in a circumnuclear burst of star formation.

INTRODUCTION

The nuclear spectra of Seyfert galaxies can be thought in terms of two components: a stellar component characterized by absorption lines from stellar atmospheres and an active component composed of strong emission lines and a featureless continuum, or FC. In the standard model for active galactic nuclei the UV/optical continuum is produced by non-thermal processes, following a power-law of the form $f_\nu \sim \nu^{-\alpha}$ with a typical value of $\alpha = 1.0$. However, hot, young stars also produce a featureless continuum which weakens the absorption lines of the older stellar population.

By comparing the strengths of the Ca II triplet ($\sim \lambda 8600$Å) and Mgb ($\sim \lambda 5200$Å) absorption lines, we can study the diluting spectrum. An analysis of the Ca II triplet features for a sample of active and normal galaxies was carried out by Terlevich, *et al.* (1990, TDT). They concluded that the relative strengths of the Ca II triplet and Mgb features in Seyferts are inconsistent with dilution of a normal galaxy spectrum by a power law continuum. They suggest that Ca II triplet, which is known to be gravity sensitive, is enhanced by the presence of late-type supergiants produced in a nuclear starburst. To determine the relative contributions of old stars, young stars and active continuum to the spectra of Seyfert galaxies, we have done a similar analysis using a larger sample, matched apertures for Ca II triplet and Mgb, and a well-defined bandpasses system for the Mgb line strengths.

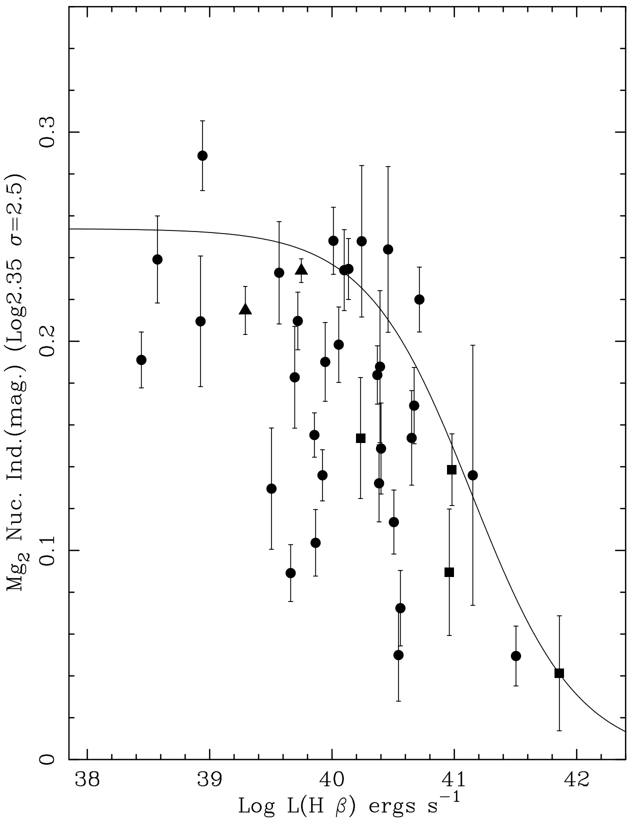


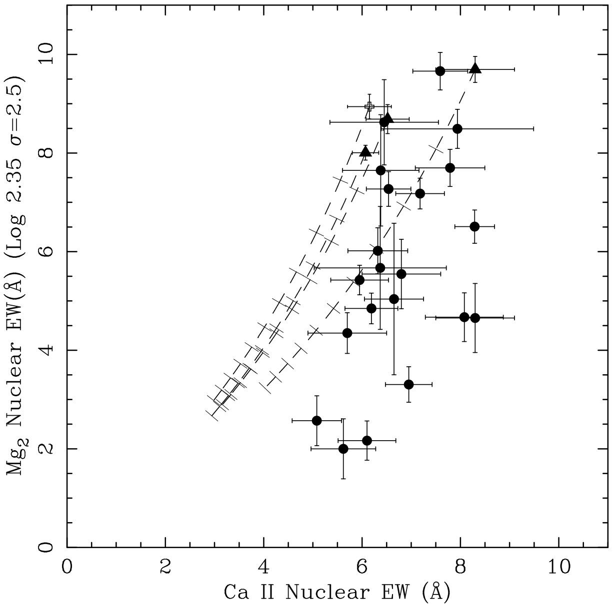
Fig. 1. The luminosity of the Hβ emission line is plotted against Mg$_2$ index corrected for the slope of the Mg$_2$ – σ_* relation. Dilution of a typical galaxy by a FC following the $L_{H\beta}$ - L_{FC} relation of Yee (1980) is shown as the solid line. Note the tendency for many Seyferts to weaker Mg$_2$ than expected.

OBSERVATIONS & PREVIOUS RESULTS

Nelson & Whittle (1995, NW95) obtained nuclear optical and near-IR spectra for a large sample of Seyfert galaxies to measure their stellar velocity dispersions, σ_*. Sample selection was based partly on the presence of stellar absorption features in published spectra, resulting in a bias toward Sy 2s. We measured the absorption line strengths in the NW95 spectra using the Burstein *et al.* (1984) bandpasses for Mg$_2$ and the TDT bandpasses for Ca II triplet. A modficiation to the Mg$_2$ bandpasses was required to avoid the [NII] line at 5200 Å. A transformtion was applied to place the Seyferts back on the standard system and gave good results in tests for sample galaxies with published line strengths. Ca II tripletis sometimes found in emission in Seyferts but this occured for only one galaxy in the sample (see NW95). Nelson & Whittle (1996), used σ_* to study the dynamics of Seyfert bulges. They find that the σ_* – M_{bul} (Faber-Jackson) relation for Seyferts is offset from that for normals in the direction of lower M/L suggesting a significantly younger stellar population.

Mg$_2$ AND Hβ LUMINOSITY

An important relationship exists between Mg$_2$ and σ_* in elliptical galaxies and spiral bulges (Bender, *et al.* 1992, Jablonka, *et al.* 1996). Using σ_* from NW95, we find that the Mg$_2$ – σ_* relation is weak in Seyferts (Pearson linear correlation coefficient, $R_P = 0.16$), which tend to have weaker lines than normal galaxies of the same σ_*. However, the correlation strengthens considerably when Hβ luminosity is included as a third parameter (at fixed $L_{H\beta}$, $R_P|_{L_{H\beta}} = 0.44, P(null) = 0.9\%$). Furthermore, the slope of original Mg$_2$–σ_* relation is recovered. The $L_{H\beta}$ dependence can be shown by first removing the dependence on σ_*. In Figure 1, we plot corrected Mg$_2$ vs. $L_{H\beta}$ revealing



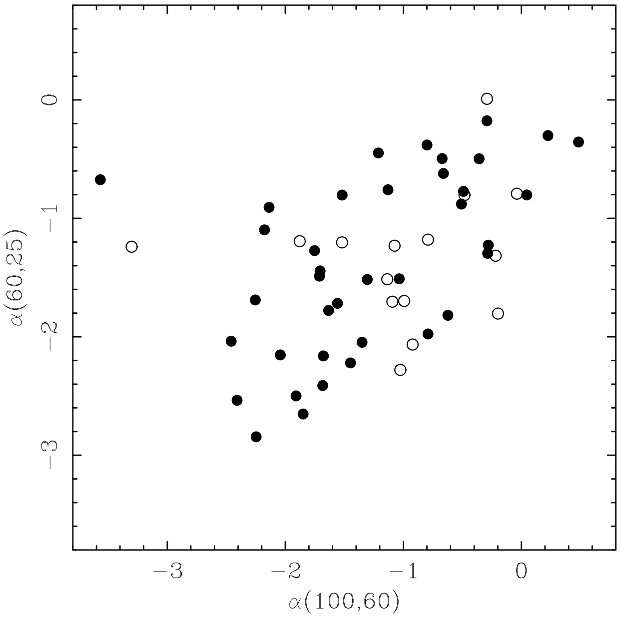


Fig. 2. The Ca II triplet and Mg_2 line strengths are plotted. The dashed lines show the tracks expected for an old stellar population diluted by power-law with $\alpha = -1.0$.

Fig. 3 IRAS Color-Color diagram. Open symbols are Seyferts with absorption line evidence for star formation. They tend to fall in the region to the lower right, amidst starburst galaxies. The filled symbols are normal Seyferts and lie on the upper left side, the region occupied by pure AGN.

a moderately strong anti-correlation ($R_P = -0.57, P(null) = 0.03\%$). One possibility is that this results from the correlation between $L_{H\beta}$ and FC luminosity for luminous AGN (Yee 1980, Shuder, 1981). If so we can calculate the expected Mg_2 assuming dilution of an old stellar population using Yee's relation between $L_{H\beta}$ and L_{FC} (curving line in Figure 1). Interestingly, in many Seyferts the Mg_2 values are weaker than expected, suggesting that the $L_{H\beta} - L_{FC}$ relation is not appropriate for Sy 2 galaxies in which the continuum is not viewed directly. Other possibilities are that the $Mg_2 - \sigma_*$ relation is different for Seyferts, or that an additional source of FC exits. These latter alternatives are suggestive of circumnuclear star formation or younger stellar populations.

We have also compared the on and off-nuclear Mg_2 line strengths in Seyferts. We would expect galaxies diluted by a point source, i.e. an AGN, to have stronger off-nuclear line strengths. This is the case for much of the sample. For some galaxies however, the line strengths on and off-nucleus are weak and equal, suggesting dilution by the same source, which must be several hundred pc across. Thus circumnuclear star formation may produce the FC in many Seyferts.

COMPARISON OF CA II TRIPLET AND Mg*b*

In Figure 2 we plot the Ca II triplet equivalent widths against those of the corrected Mg_2. For four elliptical galaxies, representing typical spheroid populations, dashed lines are drawn to indicate how their line strengths would change if they were diluted by a power-law of increasing strength. Based on these tracks we can crudely divide the Seyferts into two groups. The first group is those points which lie close to the dashed lines just below the ellipticals. These are consistent with dilution by a power-law continuum. However, because a nuclear starburst could produce similar dilution tracks we cannot rule out dilution by a starburst or a young stellar population in these objects. The second group lies off the tracks in the lower right of the diagram. For these galaxies power law dilution of an

Table 1

Starburst Indicators	**Power-Law FC Indicators**
Off Mg_2 – $L_{H\beta}$ curve	On Mg_2 – $L_{H\beta}$ curve
$Mg_{2\ \mathrm{OFF-NUC}} \simeq Mg_{2\ \mathrm{NUC}}$	$Mg_{2\ \mathrm{OFF-NUC}} > Mg_{2\ \mathrm{NUC}}$
strong Ca II triplet, weak Mg_2	Ca II triplet, Mg_2 on FC dilution track

old stellar population does not reproduce the observed line strengths. This suggests that the near-IR emission is not featureless but contains strong Ca II triplet absorption. The best explanation is that in some Seyferts red supergiants dominate the near-IR emission strengthening the Ca II triplet lines. This is consistent with a starburst contribution to the nuclear continuum as suggested by TDT.

DISCUSSION AND SUMMARY

Table 1 categorizes our results in terms of absorption line evidence for young stars or non-thermal power-law as the dominant continuum source. The consistency of these indicators is good but not perfect, that is a Seyfert with one result suggesting star formation will have at least one other.

Since far IR-colors can roughly distinguish between dust heated by AGN and dust heated by a starburst, it is interesting then to consider the far-IR colors of the sample. In Figure 3 we plot Seyferts with absorption line evidence (having at least two of the indicators in Table 1) for star-formation as open symbols on the IRAS color-color diagram (see *e.g.* de Grijp *et al.*, 1985). These tend to lie in the lower right of the overall distribution, corresponding with the region of the diagram occupied by starburst galaxies. The filled symbols lie in the region occupied by pure AGN.

From these results it appears that young stellar populations and/or circumnuclear star formation are present in many Seyferts. Furthermore it seems that a power-law featureless continuum is also present. We suggest that in Seyfert galaxies the power-law continuum is always present and the strength of the starburst component varies from object to object and may in some cases be the dominant contributor to the continuum in the optical and near-IR.

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