On the Seyfert 2 warm and cool infrared dichotomy

D.M. Alexander

SISSA, 2-4 via Beirut, 34014 Trieste, Italy

Abstract

An optical spectropolarimetric study has shown that the detectability of polarised broad Hα in Seyfert 2 galaxies is correlated to the IRAS $f_{60}/f_{25}$ flux ratio where only those Seyfert 2s with “warm” IRAS colours show polarised broad line emission. It was suggested that those Seyfert 2s with “cool” IRAS colours have highly inclined tori which obscure the broad line scattering screen.

I present here hard X-ray observations inconsistent with this picture showing that the derived column densities of warm and cool Seyfert 2 galaxies are statistically the same. I suggest that the IRAS $f_{60}/f_{25}$ flux ratio is more consistent with implying the relative strength of galactic to Seyfert emission and provide supporting evidence for this view.

Key words:
polarization - galaxies: active - infrared: galaxies - galaxies: Seyfert

1 Introduction

The unified model for Seyfert galaxies proposes that all types of Seyfert galaxy are fundamentally the same, however, the presence of a dusty molecular “torus” obscures the broad line region (BLR) in many systems. In this picture the classification of Seyfert 1 or 2 (Seyfert 1–broad permitted lines, Seyfert 2–narrow permitted lines) depends on the inclination angle of the torus to the line of sight (Antonucci, 1993). Probably the most convincing evidence for this unified model comes from optical spectropolarimetry. Using this technique, the scattered emission from the BLR of many Seyfert 2 galaxies is revealed in the form of broad lines in the polarised flux (e.g. Antonucci and Miller, 1985, Young et al, 1996, Heisler, Lumsden and Bailey, 1997).

In this unified picture the high energy central source emission (optical to X-ray continuum) is absorbed by the dust within the torus which re-emits this
energy at infrared (IR) wavelengths. Independent strong support has been
given by hard X-ray (HX, 2 to 10 keV), near-IR and mid-IR observations
(e.g. Turner et al, 1997, Risaliti, Maiolino and Salvati, 1999, Alonso-Herrero,
Ward, Kotilainen, 1997 and Clavel et al, 2000) showing that Seyfert 2 galaxies
are generally characterised by strong absorption whilst Seyfert 1 galaxies are
relatively unabsorbed.

Heisler, Lumsden and Bailey (1997, hereafter HLB) performed an optical spectropolarimetric study of a well defined and statistically complete IRAS 60µm
selected Seyfert 2 sample to determine the statistical detectability of polarised
broad lines. The objects were selected at 60µm to reduce the possibility of
biasing due to torus inclination/extinction effects and all objects were ob-
served to the same signal to noise to ensure similar detection thresholds. In
this study a striking relationship between the detectability of polarised broad
Hα and the IRAS $f_{60}/f_{25}$ flux ratio was found where only those galaxies with
warm IRAS colours ($f_{60}/f_{25} < 4.0$) showed a hidden broad line region (HBLR).
Both Seyfert 2 galaxy types were found to be well matched in terms of red
shift, overall polarisation and detection rate of compact nuclear radio emission.
Therefore, without any apparent contradictory evidence, HLB suggested that
the IRAS $f_{60}/f_{25}$ ratio provides a measure of the inclination of the torus to
the line of sight: in a cool Seyfert 2 the torus is so highly inclined that even
the broad line scattering screen is obscured. I present here HX evidence that
strongly suggests that this picture is incorrect and provide a new view that is
consistent with other observations.

2 Testing the inclination picture

One of the key supports of the unified model come from HX observations where
the nuclear extinction is directly determined from the observed spectral slope.
Seyfert 1 galaxies are characterised by little or no absorption $20 < \log(N_H) < 21$
$\text{cm}^{-2}$ whilst Seyfert 2 galaxies have significant, sometimes extreme, absorp-
tion $22 < \log(N_H) < 25 \text{ cm}^{-2}$ (e.g. Turner et al, 1997 and Risaliti, Maiolino
and Salvati, 1999). According to the HLB interpretation the cool Seyfert
2s should show higher column densities than the warm Seyfert 2s. To date
13 of the galaxies in the HLB sample have been observed with either Bep-
poSAX or ASCA. The other 3 objects have been observed by Einstien or in
the HEAO1/A survey. In the case of the HEAO1/A objects only upper limits
could be placed. For these two galaxies (NGC34 and NGC1143) I have used
the upper limits and unextincted [OIII]λ5007 emission line fluxes to predict
their nuclear extinction using the diagnostic diagram of Bassani et al (1999).
The distribution of HX derived column densities are shown in figure 1.

The derived column densities show that an optically thick structure exists in
both the warm and cool Seyfert 2 galaxy types although, significantly, there is very little difference in the distribution of column densities. The only object which does not fit the general distribution is NGC7590 which may be a Seyfert 1 with galactic dust obscuring the BLR. The overall distribution is similar to that found for the [OIII]λ5007 selected Seyfert sample of Risaliti, Maiolino and Salvati (1999) suggesting that the far-IR selects Seyferts in a reasonably unbiased manner: ∼35% of the objects are Compton thick (i.e. log($N_H$) > 24 cm$^{-2}$), the mean log($N_H$) for the whole sample is 23.2±0.9 cm$^{-2}$ and the mean for the warm and cool Seyfert 2s are 23.7±0.5 cm$^{-2}$ and 22.9±1.0 cm$^{-2}$ respectively. It could be argued that the cool Seyfert 2s are Compton thick and the determined column densities refer to the extinction suffered by the scattered emission, however, the mean log([OIII]/HX) of 0.3±1.0 and -0.2±1.4 for the warm and cool Seyfert 2s respectively suggest that this is not the case (see Bassani et al, 1999). If anything, the cool Seyfert 2s appear to be HX bright compared to the warm Seyfert 2s.

The hypothesis of HLB could still be retained with some modification (e.g. allowing different nuclear environments such as suggesting that the warm Seyfert 2s have additional gaseous extinction within the torus walls (Granato, Danese and Franceschini, 1997)). However, the simplest and most direct conclusion is that the IRAS $f_{60}/f_{25}$ colour ratio does not indicate the inclination angle of the torus in Seyfert 2 galaxies.
If the IRAS $f_{60}/f_{25}$ colour ratio is not an indicator of the inclination of the dusty torus then what does this colour ratio imply? A natural starting point is to compare the HLB Seyfert properties to those of non-Seyfert galaxies. A good comparison is the Bright Galaxy Sample (BGS, Soifer et al, 1989) which is selected at the same wavelength as the HLB sample and has a very similar flux limit. The BGS sample is partially classified by Kim et al (1995) using the optical emission line ratio technique (e.g. Baldwin, Phillips and Terlevich, 1981). To increase the number of classified objects I have taken these observations and other optical spectroscopic observations from the literature, classifying 77% of the BGS sample: 25% are found to be LINERs, 62% are HII galaxies, 12% are AGN and 1% have no emission lines. These galaxies have been classified using all the emission line diagnostics of Veilleux and Osterbrock (1987) and the mode classification for each galaxy is adopted. For brevity only the $[\text{NII}]\lambda 6583/\text{H}\alpha$ vs $[\text{OIII}]\lambda 5007/\text{H}\beta$ diagram is shown here, see figure 2.

A logical first step is to compare the IRAS colours, see figure 3. The IR warm region is clearly dominated by Seyfert 2s although the cool region also contains HII and LINER galaxies with a wide range of IRAS colours. The cool Seyfert 2s cannot be distinguished from the HII and LINER galaxies in terms

Fig. 2. The optical emission line ratios for LINERs and HII galaxies from BGS and Seyfert 2 galaxies from HLB.

### 3 The Seyfert 2 infrared dichotomy
of their IRAS emission (note there are no Seyfert 2s with $\log(f_{60}/f_{25}) > 0.9$ due to the HLB selection criteria). As the distribution of HX derived nuclear column densities are so similar it is probable that the same optically thick structure (i.e. the torus) exists in both the warm and cool Seyfert 2 galaxy types. According to the unified model, this structure should emit thermally at IR wavelengths and therefore, although the HX emission shows that a Seyfert nucleus is present in the cool Seyfert 2s, the IR emission from the torus must be dominated by galactic emission in the large IRAS apertures (as previously suggested by Alexander et al, 1999). Additional evidence for this picture is found in the distribution of optical emission line ratios where the cool Seyfert 2s have, on average, weaker $[\text{OIII}] / \text{H}\beta$ emission, see figure 2. Assuming that both the warm and cool Seyfert 2s have the same basic Seyfert nucleus and galactic emission, the lower mean emission line ratio in the cool Seyfert 2s implies a larger ratio of galactic to Seyfert activity. Indeed in one galaxy (NGC7496) the observed emission line ratio is consistent with that of an HII galaxy even though it clearly has HX emission and therefore a Seyfert nucleus.

4 Conclusions

I have presented HX observations of Seyfert 2 galaxies that are inconsistent with the HLB explanation for the IR dichotomy. From the classification of the
BGS sample I have shown that the distribution of IRAS colours and optical emission line ratios favour the IRAS $f_{60}/f_{25}$ flux ratio implying the strength of galactic to Seyfert activity. I provide further evidence for this view and explain the spectropolarimetric results in a more detailed article (Alexander, 2000).

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