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Letter to the Editor

Dust lanes, thick absorbers, and the unification model for Seyfert galaxies

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Abstract. A modification of the popular unification model for Seyfert galaxies is proposed, which takes into account recent observational findings on the statistical properties of both type 1 and type 2 Seyferts.

In the proposed scenario, Compton–thick Seyfert 2 galaxies are those sources observed through compact, thick matter (the 'torus'), while Compton–thin/ intermediate Seyfert galaxies are obscured by dust lanes at larger distances.

Key words: galaxies: Seyfert – X-rays: galaxies

1. Introduction

The discovery of broad lines in the polarized flux of the archetypal Seyfert 2 galaxy NGC 1068 (Antonucci & Miller 1985) has been a landmark in the study of AGN, leading to the now widely accepted unification model for Seyfert galaxies (e.g. Antonucci 1993). In this scenario, type 1 and type 2 Seyferts are intrinsically the same, appearing different only because in the former we can see the nucleus directly, while in the latter the direct view is prevented by absorbing matter on the line–of–sight.

There can be no doubt about the basic correctness of the unification model. In fact, there is plenty of examples of Seyfert 2s with unambiguously have an obscured type 1 nucleus at their centre, while we are not aware of even a single Seyfert 2 which certainly does not harbour a hidden Seyfert 1. However, it is likely that the strictest version of the model (in which the aspect angle is the only relevant parameter) is not fully valid. Arguments against it include:

- a) there is, on average, enhanced star formation in Seyfert 2 galaxies with respect to Seyfert 1s (Maiolino et al. 1997);
- b) the average morphologies between galaxies hosting type 1 and 2 nuclei are different, those hosting type 2 being on average more irregular (Maiolino et al. 1997, Malkan et al. 1998);
- c) there is a greater overall dust content in Seyfert 2s (Malkan et al. 1998).

Moreover, Malkan et al. (1998) showed that there is plenty of dust lanes at distances of hundred of parsecs in all type of Seyfert galaxies. They went as far as to propose that these dust lanes are completely responsible for the type 1/type 2 dichotomy, and therefore dismissing the existence of the torus. To avoid confusion, it is important to remark that here and after we use the term 'torus' to indicate any distribution of optically thick matter close (a few tens of parsecs at most) to the nucleus, and with a large covering factor, whatever its actual geometry is (not necessarily ring–shaped!). Actually, there are many good arguments in favour of the existence of the torus. Apart from those listed by Antonucci (1993), more recent ones include radio imaging and water maser measurements, indicating dense matter very close to the black hole (e.g. Gallimore, Baum & O'Dea 1997; Greenhill et al. 1996); and infrared imaging of nearby Seyfert 2s, again indicating the presence of large amount of matter very close to the nucleus (e.g. Siebenmorgen et al. 1997).

In the last few years, very strong evidence in favour of the 'torus' (whatever it really is) has been obtained from X–rays observations. In particular, BeppoSAX observations have shown that at least half of Seyfert 2s in the local Universe are Compton–thick (Maiolino et al. 1998a; Risaliti, Maiolino & Salvati 1999), i.e. the nuclear radiation is absorbed by matter with column densities exceeding 10^{24} cm^{-2} (see Matt et al. 2000 for the general properties of bright Compton–thick Seyfert 2s). While in a handful of Compton–thick sources the column density has been directly measured (e.g. NGC 4945: Iwasawa et al. 1993, Done et al. 1996, Guainazzi et al. 2000; Circinus Galaxy: Matt et al. 1999; NGC 6240: Vignati et al. 1999), in the majority of them either the column density is so large to completely obscure the nucleus even in hard X–rays (e.g. NGC 1068: Matt et al. 1997) or their flux at high energies is too low to permit a detailed spectral analysis or, often, even a detection with the present generation of hard X–ray detectors. In this case, the classification of a source as Compton–thick lies on indirect arguments: a reflection–dominated spectrum (recognized by the flat slope, if the reflector is 'cold', and by a $\sim$1 keV equivalent width iron line) is the most useful and used indicator.

The observed large fraction of Compton–thick Seyfert 2s implies that the covering factor of such thick matter must be large. Assuming a spherical geometry for simplicity, the total amount of matter is proportional to the square of the outer radius, provided that it is much larger than the inner radius (this argument holds, at least roughly, whatever is the geometry, if the covering factor is large). In order not to exceed the value of the mass obtained from dynamical measurements, the outer radius of the torus in Circinus Galaxy must be less than 20 pc (Maiolino et al. 1998b). A less tight constraint is derived from NGC 1068 (Risaliti et al. 1999), i.e $\lesssim$100 pc, which however still implies that the dust lanes on the hundred parsecs scale cannot be the matter responsible for the absorption in this source.

A further important finding of Risaliti et al. (1999) is that there is a clear difference between the N_H distribution of Intermediate (type 1.8–1.9) and strict type 2 Seyferts. While the intermediate Seyferts in the Risaliti et al. sample are all Compton–thin, the strict type 2 Seyferts have column densities generally exceeding 10^{23} cm^{-2}, and most of them are Compton–thick.

In the following section we will discuss a possible modification of the unification model which qualitatively accounts for the different statistical properties of obscured and unobscured Seyfert galaxies, and for the different column density distribution of intermediate and strict type 2 sources.

2. A modification of the unification model

The proposed modification of the unification model is illustrated in Fig. 1. The basic properties are as follows:

– In all Seyferts there are dust lanes on scales of hundred of parsecs, as observed by Malkan et al. (1998). These lanes have column densities of the order of 10^{22}–10^{23} cm^{-2} at most, otherwise the mass involved would be too large. The fact that the dust content of Seyfert 2s appears, on average, to be greater than that of Seyfert 1s may be related to the more disturbed morphology of the Seyfert 2s host galaxies, possibly as a result or a recent interaction with another galaxy.
– Not all Seyferts have the torus (or, at least, not all have a torus with a large covering factor). Again, there may be a greater chance of producing a torus in Seyfert 2s, as they are more disturbed and with a larger overall dust content.

There are, therefore, three different possibilities:

– The sources observed through a dust lane (but outside the torus) are the Compton–thin (in X–ray terminology) or intermediate (in optical terminology) Seyferts.
– The sources observed through the torus are the strict Seyfert 2s (most of them Compton–thick, using the X–ray terminology).
– If the line–of–sight to the nucleus is free of any absorber, the source is a Seyfert 1. Of course, it is more likely (but not necessary) that a source is observed as Seyfert 1 when the torus is not present.

It is worth remarking that the fraction of sources with the thick torus must be fairly large, as Compton–thick sources account for at least half of the total number of obscured Seyferts (Risaliti et al. 1999).

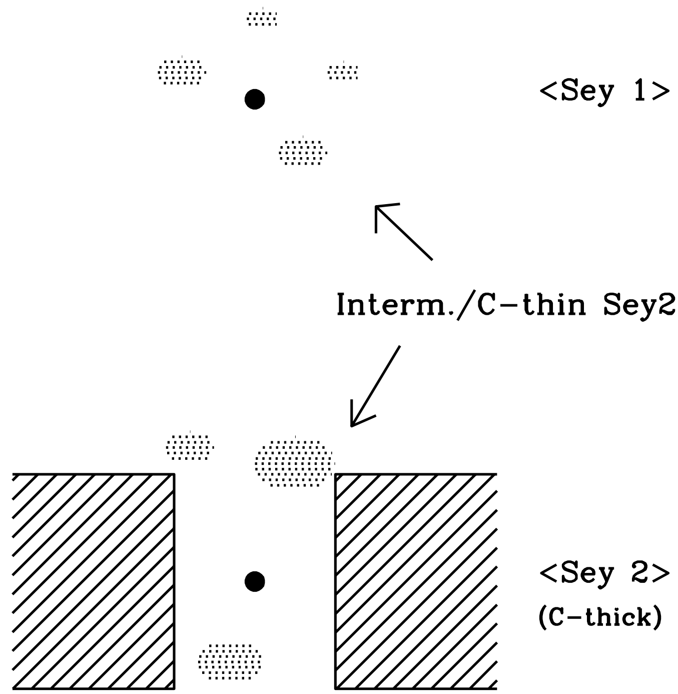

Fig. 1. The proposed unification model (see text for details).

3. Discussion

The proposed modification, while retaining the basic and most successful characteristic of the unification model (i.e. that all intermediate and type 2 Seyferts harbour an obscured type 1 nucleus), explains, at least qualitatively, the observed differences between the average properties of Seyfert 1s and Seyfert 2s and between the column density distributions of intermediate and strict type 2 Seyferts. This model is somewhat different (even if on a similar line of thought) from that proposed by Maiolino & Rieke (1995), and takes into account recent observational results. The two ‘flavours’ of Seyferts, with and without the thick torus, may represent either two different branches in the AGN evolution, or a different evolutionary stage in the life of any (or most) source.

Testing the proposed model would require further studies of the statistical properties of Seyferts, which caution in separating intermediate and strict type 2 sources. For instance, as the torus is expected to be axially symmetric (while the dust lanes are probably more randomly distributed), a correlation between Compton-thick absorption and presence of ionization cones and large polarization is expected. Another test is to search for the presence of the torus in Seyfert 1s, as we predict that many sources of this class do not have it. This may be done either by searching for strong IR emission (which however may be related to starburst rather than reprocessing of UV/X–rays from thick matter), of by searching for signatures of X–ray reprocessing (e.g. Ghisellini, Haardt & Matt 1994; Krolik, Madau & Życki 1994). The latter way have already produced a clear case of a Seyfert 1 *with* the torus: NGC 4051 was caught by BeppoSAX when the nuclear emission was switched–off, and clear evidence for reprocessing by large amount of optically thick distant matter was present (e.g. a $\sim$600 eV equivalent width iron line and a cold reflection continuum, Guainazzi et al. 1998). However, this kind of observations based on variability requires rather extreme behaviours of the X–ray emission, and it is not clear how common a switching–off of the nucleus can be. More promising is to search for narrow (i.e. unresolved) iron Kα lines in addition to the relativistically broadened component from the accretion disc. When the nuclear X–ray emission is directly visible, equivalent widths of the order of 50–100 eV are expected from the torus (Ghisellini, Haardt & Matt 1994). While ASCA and BeppoSAX results have been rather ambiguous in this respect, such a search is certainly within the capabilities of XMM.

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