

SEYFERT 1 & 2 GALAXIES AND THE UNIFIED MODEL OF AGN

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ABSTRACT

In 1943, astronomer Carl Seyfert conducted the first [Kaufman & Freedman, Universe, Fifth Edition] systematic study of galaxies exhibiting an especially bright nucleus [Facts on File Dictionary of Astronomy, The 1994]. Based on his studies, astronomers now refer to these galaxies with unusually bright nuclei as Seyferts. Years later, in the mid-1970's, Khachikian and Weedman found that Seyferts fell into two spectroscopic classes: those with both narrow and broad emission lines (Sy type 1) and those with narrow emission lines only (Sy type 2) [Peterson & Wilkes 2000]. The primary accepted difference in the two is that Sy1 galaxies are viewed face on from earth, while Sy2's are inclined. Except for inclination, Sy1 and 2 galaxies share several intrinsic commonalities. These commonalities have resulted in Sy1 and Sy2 galaxies being grouped as Unified Models of Active Galactic Nucleus (AGN).

However, in recent years the "Unified Model of Seyfert galaxies has been thrown into doubt (SAO, Essay Guidelines)." This paper will discuss an article published in 1999 titled The Close Environment of Seyfert Galaxies and Its Implication for Unification Models [Peterson & Wilkes 2000], hereafter referred to as the Unification Model Challenge Paper (UMCP). In reviewing the UMCP, I will apply several questions to try to deduce whether or not UMCP has credibility. Is the UMCP paper correct? Could the result of the UMCP be from a selective effort in the way the researchers picked the sample galaxies? I will draw upon several sources, including articles published after the UMCP, and give my opinion.

1. ASSERTIONS OF THE UMCP & OTHER VIEWS

Early in the UMCP, the authors confirm that there is an intrinsic difference between the environment in Sy1 and Sy2 galaxies, but disagree that the only difference is viewing orientation.

Another paper which challenge the unification model, by Peterson and Wilkes also points out that the simple unification hypothesis, where Sy2's are intrinsically Sy1's dependent on the direction of the observer, had two major problems: (1) why is the AGN continuum source extinguished by only a factor of a few, but the broad lines by a larger factor? and (2) the shape of the Sy2 continuum does not resemble the dust-attenuated Sy1 AGN continuum, that is, Sy2 continuum are not highly reddened by passage through a medium in which the absorption or scattering decreases with increasing wavelength. Peterson and Wilkes explain that in the early 1980's Antonucci and Miller found the polarization spectra of Sy2 galaxies exhibited broad emission lines similar to those seen

in Sy1 spectra. This was interpreted as the result of scattering of light by dust or electrons, into our line of sight. Therefore, depending on the viewing angle, the observer may see either a Sy1 or Sy2 (Figure 1).

Peterson and Wilkes go on to say that as more Sy2 galaxies and low-luminosity AGN are observed in polarized light, the more edge-on Sy1 galaxies are being discovered. They state that current studies show a detection rate of ~50% for Sy2 galaxies with polarized broad lines. The implication, according to their paper [Peterson & Wilkes 2000], is either many Sy2 galaxies do not possess a scattering region or they do not have a BLR.

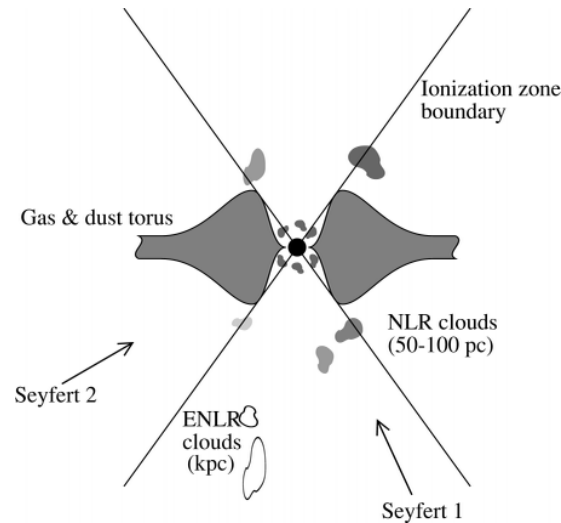


Figure 1
The conceptual scheme for unification of Sy1 and Sy2 galaxies (not to scale) with an optically thick torus of cool material surrounding the continuum source (central circle) and the broad emission-line region (BLR, small 'clouds' surrounding continuum source). From Peterson (1997), originally from R W Pogge.[Peterson & Wilkes 2000]

Support for the unified model of AGN is found in the paper titled NGC1068: Prototypical Seyfert 2 Galaxy [Capetti, A. 2000]. Capetti states matter-of-factly that NGC1068, a Sy2 galaxy, harbors a Seyfert I nucleus which is hidden to our view by obscuring material, probably arranged in a torus or on a highly warped disk. He bases this statement on the evidence that the polarized spectrum of NGC 1068 closely reproduces the spectrum of a Sy1 galaxy with the presence of broad permitted hydrogen and iron lines. Due to the vertical height of the torus, ~0.1 to 1pc, light from the nucleus can only reach us after it has been scattered into our line of sight; therefore polarized [Capetti, A. 2000].

One of the main arguments asserted in the UMCP, and I believe the foundation for the paper, is that statistically there was evidence of excess companion galaxies for Sy2 galaxies within 100 Kpc and within a search radius of three times the diameter ($3D_S$) of each Seyfert galaxy. Sy1 galaxies did not show the same excess in companions for the same linear distances. The implication being that strong interaction between a Sy2 galaxy and a comparable sized companion enhances starburst formation, which drives molecular gas and dust toward the galaxy center, which may obscure the nucleus [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999].

2. OBSERVATIONS OF THE UMCP

In all, 72 Sy1 galaxies and 60 Sy2's were sampled. While the numbers are statistically significant, the authors of the UMCP did state that the search radius should be increased from 100 Kpc to more than 500 Kpc [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999]. This increase in distance should result in a larger sampling, and therefore, a higher statistical validity.

One of the most interesting findings in the UMCP was, of the 72 Sy1 galaxies and 72 Sy1 control samples, the expected percentage of companions, 39% and 40%, was found to be statistically acceptable. *However*, of the 60 Sy2 galaxies and 60 Sy2 control samples, there was a 70% vs 42% difference for companion galaxies within $3D_S$ (galactic diameters). The expected percentage from Poisson statistics is $\approx 34\%$ and 26% respectively. The statistical significance is that Sy2 galaxies appear to have companions by more than twice what is predicted within 100 Kpc [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999]. Unless this were predicted elsewhere by another research group, the fact that Sy2 galaxies have host companions at twice the Poissonian distribution is in itself a finding which warrants additional studies.

The study points out that while Sy2 galaxies have an excess of companions, Sy1's do not, and if Sy1's do not have an excess of companion galaxies, then what about quasars? The UMCP points out that evidence provided thus far about the occurrence of quasars in interacting host galaxies is based on few objects and therefore statistically not acceptable. [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999]

The research group does point out that two other studies conducted in 1997 and 1998, which were limited in their data, found that the environment of Sy1 differed from Sy2, even though one paper discounted any statistical significance where the companion frequency for Sy2 was higher.

3. BIASES IDENTIFIED IN THE UMCP

The UMCP included only those galaxies with a galactic latitude located at $b \sim > 40^\circ$. According to the UMCP, including low galactic latitude fields would have produced a bias toward a lower fraction of companions because of the difficulty in identifying them on the DSS because of confusion with other stars and extinction. The research team also made an effort not to match absolute magnitudes since this could skew the control sample toward intrinsically more luminous objects. [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999]

The UMCP points out there is a bias in the DSS against low surface brightness galaxies and compact galaxies. This is acceptable since it is applied to the entire study, especially since galaxies selected were compiled from a study based solely on a survey of galaxies with an excess of UV. [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999]

The authors of UMCP state that other papers reference in the UMCP ignored the environment beyond $3D_S$ of the host galaxy. In addition, the authors recognized there may be a bias using $3D_S$ anyway since the Sy galaxies themselves vary in diameter. Why not use 60 or 100 Kpc as D ? Section 5. Conclusions points out that $3D_S$ (60-80 Kpc) may be inadequate. [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999] A fundamental question to be asked is why was the search radius set at 3-Seyfert diameters ($3D_S$)? This may be due to the reference documents used in UMCP. This is a personal question for which I have no answer.

4. CONCLUSION

In its simplest form, the UMCP asserts that the majority of Sy2 galaxies are obscured Sy1 galaxies. But it goes on to state that inclination is not the only difference in Seyfert galaxies [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999] as stated previously.

I believe including galaxies with $b \sim > 40^\circ$ has validity. As pointed out in the Biases section, by excluding galaxies with $b \sim < 40^\circ$, the researchers were also able to avoid extinction and confusing galactic stars.

There is, in my opinion, much that can be discussed about unified models of AGN, but this essay was limited to a maximum number of words. Earlier, I mentioned that the UMCP sampling of 60 Sy2 galaxies and the difference of 70% having companion galaxies within $3D_S$ and the expected Poisson statistics of $\approx 34\%$. The statistical significance is that Sy2 galaxies appear to have companions by more than twice what is predicted within 100 Kpc [Dultzin-Hacyan, Krongold, Fuentes-Guridi, & Marziani 1999]. Unless this were predicted elsewhere by another research group, the fact that Sy2 galaxies have host companions at twice the Poissonian distribution is in itself a finding which warrants additional studies. I would like to see another study conducted, similar to UMCP, but expand the search area, as recommended, to a radius >500 Kpc.

I would like to have seen a short list of the Sy1 and 2 galaxies, and the sample galaxies used for this study.

While the UMCP (and Peterson and Wilkes) exhibits compelling evidence that Sy1 and Sy2 galaxies are the result of their environment, Capetti seemed to support the unified model of AGN. To perform a detailed study on the UMCP, one would need to review the reference documents cited in the UMCP paper, but that was not the objective of the paper.

When I started reviewing the UMCP, I must admit that I had NO knowledge of the unified model scheme; therefore, I feel that I was predisposed to agree or disagree. In preparing this paper, I actually changed my mind three times and must admit I still have some doubts. But I am finding the more I read, the more convinced I am that I can not support the unified model of AGN.

5. REFERENCES

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ACKNOWLEDGEMENTS

This paper was prepared by the author as part of the curriculum requirement of ©Swinburne Astronomy Online (SAO). Thanks to Dr. Brad Gibson (SAO) and Joanie Mickle for editorial comments.