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NEW INSIGHTS ON THE STARBURST-AGN CONNECTION

Roberto Cid Fernandes

Depto. de Física, UFSC, Florianópolis, SC, Brasil (cid@fsc.ufsc.br)

Henrique R. Schmitt

STScI, Baltimore, USA (schmitt@stsci.edu)

and

Thaisa Storchi-Bergmann

Instituto de Física, UFRGS, Porto Alegre, RS,Brasil (thaisa@if.ufrgs.br)

RESUMEN

Hacemos una revisón de evidencia reciente acerca de la conección entre formación estelar y actividad nuclear en galaxias Seyfert. La actividad tipo AGN y la formación estelar podrían darse en ciclos de $\sim 10^8$ años de duración, con una posible liga evolutiva entre las propiedades del AGN y la edad de la población estelar.

ABSTRACT

We review recent evidence for a connection between star-formation and nuclear activity in Seyfert galaxies. We speculate that AGN activity and star-formation occur on "cycles" of $\sim 10^8$ yr, and that there may be an evolutionary link between the AGN properties and the age of the nuclear stellar population.

Key Words: **GALAXIES: ACTIVE, SEYFERTS — STARS: FORMATION, EVOLUTION**

Type 2 Seyferts have been at the heart of the starburst-AGN connection debate in the past few years. The debate centered on the origin of the excess blue light seen in Seyfert 2s when compared to normal galaxies. Before the days of unification this defining characteristic of Seyfert 2s was traditionally modeled as a power-law featureless continuum (FC), presumably emanating from the AGN. But when the unified model hid the nuclei of Seyfert 2s behind an opaque dusty molecular torus (elegantly explaining the spectropolarimetry data, ionization cones, etc.), we had to abandon the idea that the FC comes from the nucleus. Part of it ("FC1") is of course scattered nuclear light, but most ($\sim$ 80%) originates in an extended, unpolarized source ("FC2").

To verify whether FC2 is due to a circumnuclear starburst (maybe within the molecular torus itself, which after all is a dense molecular cloud, and thus a natural site for star-formation), one has to face the difficult task of identifying features of massive stars in an AGN spectrum. Young starbursts ($< 10^7$ yr) are best detected in the UV, and indeed Heckman et al. (1995) find that the IUE spectra of Seyfert 2s resemble those of reddened starbursts. Later, HST-UV spectra revealed unambiguous signatures of massive stars (CIV and SiIV P Cygni lines) in Mrk 477, NGC 5135, NGC 7130. (Heckman et al. 1997, González-Delgado et al. 1998). Identifying massive stars in the optical is harder, but things get easier when the starburst is in a WR-phase. WR features have been detected in Mrk 477 (Heckman et al. 1997), Mrk 1210 (Storchi-Bergmann et al. 1998), Mrk 463E (Heckman 1999), and others -configuring an epidemics of WR stars in Seyfert 2s! All these galaxies are known to harbour obscured Seyfert 1 nuclei, and suffer from the FC2 syndrome. The detection of massive stars leaves little doubt as to the origin of FC2 in these Seyfert 2s. Though we do not know whether NGC 5135 and 7130 have a FC2 problem, the detection of starburst features in these (and others; Cid Fernandes et al. 1998 and references therein) composite Seyfert 2s advances the case for a link between star-formation and AGN activity.

If the story ended here one would get the uncomfortable impression that every starburst in Seyfert 2s is younger than 10 Myr. As most of the results to date stem from UV observations, thus favoring detection of young systems, one should not be so surprised to find what is being looked for. Still, the question remains of whether Seyfert 2s also harbour older "starbursts". Parallel to the UV work, we have carried out an optical spectroscopic study of stellar *absorption* lines in a sample of 42 active galaxies (Cid Fernandes et al. 1998; Storchi-Bergmann et al. 1998; Schmitt et al. 1999), aiming a global characterization of their stellar content. If star-formation and nuclear activity are somehow connected, a comparative study of the stellar populations of normal and active galaxies should reveal traces of this connection.

In Schmitt et al. (1999) we used data for the nuclei of 20 Seyfert 2s and 4 radio-galaxies to perform population synthesis calculations, by decomposing the data in terms of a star-cluster base library spanning a range of ages and metallicities, plus a $F_\nu \propto \nu^{-1.5}$ AGN-like component. Compared to elliptical galaxies, we find that 80% of the sample have larger contributions of 10^8 yr stars. Larger fractions of younger populations are also found, but the difference in the 10^8 yr age-bin stands out. This excess population is also present in comparison with bulges of early-type spirals, where most Seyferts live (Storchi-Bergmann et al. 1999). We concluded that *the main difference between the stellar populations of Seyfert 2s and of non-active elliptical or early-type spirals is the presence of a larger fraction of* $\sim 10^8$ *yr stars.* This result indicates that the starburst-AGN connection extends beyond the first 10 Myr. The ubiquitous 10^8 yr time-scale calls for physical interpretation. Perhaps it reflects some sort of *activity cycle*, during which AGN and star-formation go hand in hand, possibly due to feeding mechanisms. Since 10^8 yr is $\sim 1\%$ of the Hubble time, a causal link between star-formation and AGN activity would imply that $\sim 1\%$ of the galaxies should be active, in rough agreement with current estimates.

It is highly instructive to consider the question of *why* it took us so long to realize that $\lesssim 10^8$ yr stars make up a substantial fraction of the observed optical-UV light in Seyfert 2s, and we direct the reader to Storchi-Bergmann et al. (1998, 1999) for a discussion. Essentially, this has to do with the little attention devoted to starlight in AGN studies, which traditionally model it out with an elliptical galaxy spectrum. But nuclear stellar populations of elliptical galaxies and AGN host galaxies are different! Ellipticals have deep metal lines, which when compared to the spectra of Seyfert 2s (richer in $\leq 10^8$ yr stars) creates the false impression that these lines are diluted by a strong FC. The only truly *featureless* continuum is the one scattered from the hidden central source, which contributes less than 10% to the optical light.

One way to further our understanding of how the star-formation-AGN connection actually works is to establish whether the AGN "knows" about its stellar environment and vice-versa by examining correlations between their properties. It is particularly important to establish whether the *age* of the stars in the inner regions of active galaxies correlates in some way with the activity level. If the AGN and its surrounding stars somehow influence each other, one intuitively expects that the AGN properties might change as the starburst ages. Consider, for instance, the cases of Mrk 463E, 477 and 1210. The $\sim$ 3–6 Myr starbursts in these Seyfert 2s are bound to evolve. Will the AGN evolve along? What will these Markarians look like 10 or 100 Myr from now? Will they still be Seyfert 2s, or will they turn into Seyfert 1s, LINERs, or dormant AGN? Which known objects correspond to this later stage? These are fascinating questions to which we still do not have answers.

We also need to extend such studies to Seyfert 1s. Star-formation must also be occurring in Seyfert 1s (and QSOs?) -they are after all face-on type 2s- but the contrast with the bright nucleus complicates the detection of stellar features. The case of NGC 7582 is illustrative of how much one can learn here. Before its incredible outburst (described in I. Aretxaga's contribution), NGC 7582 *was* a composite Seyfert 2/Starburst system, with clear signs of recent nuclear star-formation (a cousin of NGC 5135?). Now that it has turned into a type 1 (violating the unified model and showing how much is yet to be learned in AGN), we know that at least one Seyfert 1 has a circumnuclear starburst. How many more are out there and what their properties are?

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