Magnetically Driven Outflows in Starburst Systems

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1. Introduction

Active Galactic Nuclei (AGNs) produce large amounts of energy coming out from a small volume (from Seyfert galaxies to QSOs, L = 10^{43-48} ergs/s) and th e nature of the central engine remains virtually unknown. Current theories include: i) black holes (BHs) accreting matter from the surroundings (e.g. Rees 1 984); ii) starbursts (SBs) in which activity is due to star formation in a central cluster (Terlevich et al. 1992 – who have revived old theories from, e.g., Shklovskii 1960); and iii) BHs surrounded by starburst clusters (e.g., Williams and Perry 1994). W hile BHs have the power to produce the observed luminosities and provide a preferred axis for collimating jets, they seem to explain unsatisfactorily, e.g., the broad emission-line regions (BELRs) of AGN (as they require a fine-tuning to fit the observations). In Starburst models, on the other hand, strongly radiative compact supernova remnants (cSNRs) are the source of the broad emission lines. This model has been proved plausible in explaining the observed emission line spectrum, the UV-optical continuum and related variability (e.g., Terlevich et al. 1992), but is difficult to be applied to the whole population of AGN. For example, they do not provide a natural mechanism for jet production and collimation.

Starbursts and a compact AGN activity (with a BH) may coexist in the nucleus of luminous infrared galaxies (the so called LIGs which have extreme mid-to far-IR luminosities, $L_{IR} > 10^{11} L_{\odot}$). The question to assess the relative contribution of each form of activity to the LIGs energetics, and to determin e a potential evolutionary progression from one to the other has been recently addressed by Smith, Lonsdale & Lonsdale (1998). They have demonstrated that nuclear starbursts can in principle explain the observed VLBI- and VLA- scale structures and the high infrared luminosities of most of these objects. A LIG prototype, Arp 220, for example, is dominated by a nuclear SB imbedded in a rotating disk of molecular gas. This could favor an evolutionary interpretation in which an SB eventually begins to fuel a coaliscing central object.

Nuclear outflows have been detected in several Sey galaxies and LIGs (e.g., Arp 220, NGC 6240, NGC 2782, NGC 4945, and NGC 4235; see, e.g., Colbert et al. 1996, Jogee et al. 1998). Since it seems plausible that the LIGs and perha ps some of the low-level-activity AGN class of Sey galaxies may be powered by nuclear SBs at least during part of their active lives, in this work we assume that an SB (which has been induced in a merging process) is in progress in the nuclear region of these objects and examine the conditions under which collimated outflows could be produced in such a scenario.

2. Starburst Scenario

We have investigated the evolution of SB stellar clusters (de Gouveia Dal Pino & Medina Tanco 1997, 1999) and found that: i) part of the gas released by star formation may cool quickly by free-free emission in time scales << than the evolutionary time scales of the system ($\leq 10^8$ yr) and thus fall towards the centre and settle into a disk (see, e.g., Figure 1 of de Gouveia Dal Pino & Medina Tanco 1999); and ii) massive nuclear SBs with cluster masses $M_c \sim 10^9 - 10^{10} M_{\odot}$, core disk masses $M_d \sim 10^8 - 10^9 M_{\odot}$, and supernova rates $\upsilon_{SN} \sim 5\ 10^{-3} - 2\ yr^{-1}$ (which are consistent with the values inferred from the observed non-thermal radio power in source candidates) may inject kinetic energies $10^{41} - 10^{43}$ erg/s - which are high enough to blow out directed flows from the disk surface, within the SB lifetimes.

3. Magneto-centrifugally Driven Outflows in SBs ?

Collimated winds may be accelerated from a rotating gas disk with a magnetic field (**B**) anchored into it (e.g., Pelletier & Pudritz 1992). The **B-**field and the disk structure determine how much mass is launched out of the disk.

Based on the model for disk formation above and on empirical conditions derived for the disk of the LIG prototype (Arp 220), and the magnetized outflows of Sey galaxies and LIGs, we find that magnetic fields with intensities $8x10^{-4}$ - $5x10^{-2}$ G are able to accelerate the flows up to the observed terminal velocities, which for LIGs are (de Gouveia Dal Pino & Medina Tanco 1999)

$$v_\infty \approx 973 \text{ km/s} \left(\frac{\Omega_e r_e}{282 \text{ km/s}}\right) \left(\frac{r_i/r_e}{0.14}\right)^{-0.45}$$

where Ω_e is the disk angular velocity at the radius r_e which determines the maximum radius of the outflow zone in the disk, and r_i is the corresponding minimum radius of the outflow zone.

Using wind mass losses