Galactic mergers, starburst galaxies, quasar activity and massive binary black holes

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Many quasar-like objects show evidence for massive binary black holes[1]. The recent discovery[2] of a massive ($5\times10^6\,M_\odot$) object in the centre of the local group dwarf elliptical M 32 greatly raises the probability of forming such binaries through galactic mergers. Here I argue that the enhancement of all kinds of activity (quasar-like activity and star formation) in galaxies with companions is not so much a consequence of tidal interaction between the massive galaxies as the result of collisions with their dwarf satellites.

Recent studies have shown that interactions between galaxies play a role in stimulating nuclear activity[3]. Imaging studies of high luminosity quasars[4,5] reveal that more than 30% have normal companion galaxies very close to them (here I use the term 'normal' galaxy to refer to any galaxy with a mass of $10^{11}M_0$ or more and refer to companion galaxies with masses much less than this as 'satellite' galaxies). Surveys of normal galaxies show that close pairs of galaxies are more likely to show activity characterised by optical emission lines[6,7] and radio emission[8] than are isolated galaxies. These results support the idea that most or all normal sized galaxies have massive black holes in their centres[3]. For simplicity I will assume that all normal galaxies have massive ($\geq10^6\,M_\odot$) black holes in their centres (it makes little difference here if the percentage is actually as low as 20%, as could be the case). The enhanced nuclear activity in pairs of galaxies would seem also to support an idea proposed by Toomre and Toomre[9] that close encounters may drive gas into the nuclear regions of a galaxy and either feed the central black hole directly or lead to a burst of star formation within the inner nuclear disc[7] which could indirectly increase the fuel supply rate. In addition to the enhanced nuclear activity close pairs of galaxies have enhanced star formation rates (as evidenced by far infrared emission[10]).

There are two problems with the Toomre and Toomre scenario. First, although a close pair of galaxies (with a projected distance of ~3 Holmberg diameters or less) is more likely to be active (as a Seyfert or radio galaxy), the majority of such galaxies (>75%) do not show nuclear activity. The mechanism is therefore less than 100% efficient or there is some other factor involved. The second problem is that although close encounters can wreak havoc on the outer parts of galaxies, the motions of the stars and gas in the tightly gravitationally bound cores are unaffected.

The solution I propose to these problems is that it is not actually the detected neighburing galaxy that is triggering quasar activity (or star formation) but instead a direct collision with one of the several dwarf satellite galaxies in the system. There is then no need to invoke some subtle action at a distance (tidal?) effect. Although the statistics of these dwarf satellite galaxies are poorly known, since they are difficult to detect beyond our local group, there are probably several (2-10) associated with each normal galaxy like our own[11]. I will here use the term 'dwarf' galaxy to refer to ellipticals and irregulars with absolute magnitudes in the approximate range $-14>M_V>-18$ (and hence ignore systems such as the Draco dwarf spheroidal). In our own local group there are two magellanic irregulars associated with our galaxy and four dwarf ellipticals associated with M31 in Andromeda.

In the scenario I propose here the statistical enhancement of quasar-like activity in close pairs of galaxies arises because of the increased probability of a merger with an unseen dwarf satellite galaxy when two normal galaxies are close. A 10^8-$10^{10}\,M_\odot$ dwarf galaxy near a Seyfert is hard to detect with present techniques and the only sign of a collision or merger might be the enhanced quasar-like activity and/or a burst of star formation (perhaps creating a 'starburst' galaxy). I suggest that the type of activity produced is a function of the Hubble type of the colliding satellite galaxy and the impact parameter. The amount of visible damage is also obviously going to depend on the mass of the dwarf. If a magellanic irregular galaxy hits a spiral galaxy anywhere the most probable result is a burst of star formation. If it hits the nucleus the resulting gas input and star formation could result in quasar-like activity as well. On the other hand the impact of a small elliptical galaxy, devoid of dust and gas, on the outer regions of a spiral galaxy will probably be much less spectacular. Perhaps only a distortion of the disc and spiral arms of the galaxy will occur (a dwarf elliptical satellite has typically 1% of the mass of a normal spiral and that the stars themselves do not collide).

The collision of a dwarf elliptical with a nucleus containing a dormant (or almost dormant) black hole will be more interesting. Unlike magellanic irregulars, the majority of dwarf ellipticals have strong central mass concentrations[12]. Tonry has produced powerful evidence that the 'spike' in the centre of M 32 is caused by a $5\times10^6\,M_\odot$ black hole. It would seem likely that the spikes in the luminosity profiles of other dwarf ellipticals are due to similar black holes. In a collision, if the impact parameter is small enough, the nucleus of the dwarf elliptical will be captured by the nucleus of the larger galaxy. The two black holes will go into orbit[1,13]. The distribution of stars in phase-space around each black hole will be severely perturbed, resulting in an increased fuelling of one or both black holes. I have proposed elsewhere[1] that the displaced broad-line peaks seen in many objects are the result of such orbital motion and argued that the velocities seen are consistent with the evolution of supermassive binary black holes. The discovery of a black hole in a dwarf elliptical now makes the creation of such binaries much more probable since there are an order of magnitude more dwarf galaxies than normal galaxies and the probability of mergers is correspondingly greater.

Detailed computer simulations of mergers of galaxies of all Hubble types and sizes taking into account both stars and gas need to be undertaken, as collisions of normal galaxies with dwarf satellite galaxies offer a likely explanation of both starburst galaxies and quasar-like activity. The Hubble Space Telescope could well reveal the results of the collisions when high spatial resolution studies of active galaxies are made.

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