TIDAL TRIGGERING OF SEYFERT GALAXIES AND QUASARS: PHYSICAL SUFFICIENCY

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ABSTRACT. Excess optical and radio emission in nuclei of Seyfert galaxies and quasars is observationally related to nearby companions. Dahari found Seyferts are more strongly perturbed tidally by companions than normal spirals are. QSO data suggests a similar relationship. Quasar and Seyfert activity are thought to be fueled by gas inflow to the nucleus. To study whether gravitational tides from companions cause inflow from the spiral's disk, we use a self-gravitating 60,000 particle disk in Miller's polar n-body program. The perturbation to produce levels of inflow required for activity matches Dahari's Seyfert triggering level. QSO's are also perturbed by observed companions more than necessary for high inflow. We reanalyze Dahari's data to find that at least the majority of Seyferts are in multiple systems. Tidal triggering thus could be the main cause of Seyfert activity.

1. INTRODUCTION

Seyfert galaxies and quasars both appear to occur in spiral galaxies characterized by excess optical and radio emission in their nuclei. In both, inflow of gaseous matter to an "engine" in the nucleus is thought to fuel the activity (e.g. Simkin et al. 1980, Dahari 1984, Hutchings and Campbell 1983).

Dahari (1984) studied ~100 Seyferts and a matched angular size sample of about 300 control spirals. He searched for companions of the Seyferts measuring the sizes of both and their separations from one another. Dahari found that more Seyferts had companions than controls did (37% to 21%). Using the empirical relation between mass and galaxy size, Dahari's data gives (companion mass/Seyfert mass)/(separation/Seyfert radius)^3 = the tidal perturbation of the Seyfert by the companion. Dahari found that Seyferts are perturbed more strongly by their companions than the controls are. Only 1% of controls are perturbed at a level > 0.1 compared to 7% of the Seyferts. At levels from 0.006 to 0.1, he found 9% controls versus 18% Seyferts. At lower levels, the percentages were about equal. We see that companions may trigger Seyfert activity.

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One might question the importance of tidal triggering of activity since Dahari found only 37% of Seyferts had companions. We examined Dahari's data further and found this to be a result of Dahari prudently not searching for small companions that might be confused with stars. Also, Dahari did not search for companions beyond three times the diameter of the Seyfert or control. The former selection effect is strongly redshift dependent. By examining the low redshift portion of the sample to remove the above selection effects, we find that 75 to 90% of Seyferts have companions. We used measurements by Dahari (1985) and other sources of data to insure that these percentages are for physical companions with redshifts close to the Seyferts' (Byrd et al. 1987).

The high companion percentage implies that tidal triggering may be the main cause of Seyfert activity. However, observational correlations can be fallacious. An example would be the rancher who thinks vultures kill the dead cows he finds because of the observational correlation between the two. Here, and in our study, a test of physical sufficiency would help validate the hypothesis.

2. METHOD

We test physical sufficiency by using simple computer models of tidally perturbed disk galaxies. The required levels of mass inflow for Seyfert activity are commonly cited between 0.1 and 1.0 $M_\odot$/yr. We ask whether levels of tidal perturbations in the model that produce the required inflow match Dahari's observed perturbations. We perturb our galaxies two ways: with a perturber in a direct parabolic orbit and with a distant perturber fixed relative to the disk spin (Byrd et al. 1986b).

Our computer model uses Miller's two dimensional polar n-body program to calculate the behavior of the self-gravitating galaxy disk using 60,000 particles. Besides this component, we insert an inert "halo" component whose mass relative to the disk is designated, Q_O. We define as "active" an encounter with a companion in which about 400 disk particles are thrown into orbits crossing the inner 5% of the disk radius. If we consider a 2×10^{11} $M_\odot$ galaxy with 1/3 the mass in a 10 kpc disk and 10% of the disk mass as gas, the minimum required inflow is about 10^8 $M_\odot$ of gas during the ~two disk revolutions of the encounter. This is about 0.2 $M_\odot$/yr, within the required range. Though beyond the scope of our simulations, these gas clouds should inelastically collide with other gas to fuel the nucleus.

3. RESULTS VERSUS OBSERVATIONS

We find that strong perturbations cause strong inflows and weak perturbations none. For disks with no halo and a simulated stellar velocity dispersion matching that of our galaxy, the transition occurs at perturbations of 0.006. The disk velocity dispersion determines the transition level. For disks with high mass halos, the perturbation for required inflow is ~0.1. Recall that there are about three times as many Seyferts perturbed at levels above 0.006 than normal galaxies are.

Seven times as many Seyferts are perturbed above 0.1 than normal galaxies. Within all the uncertainties, the agreement of the levels seems reasonable. The few apparently solitary Seyferts in the low redshift portion of Dahari's sample are mainly E or SO galaxies, expected for merger remnants. Simulations indicate disk galaxies quickly merge with close companions (Byrd et al. 1986a).

For QSO's, Stockton (1982) examined low redshift quasars with compact companions nearby and concluded that: the objects were only a few kpc from the QSO's, at least 20% of the QSO's may have such objects nearby, and that the objects are probably cores of galaxies that have interacted with the QSO galaxies. Companions of comparable masses several galaxy diameters (much less a few kpc) generate a tidal perturbation greater than 0.1, the triggering level we found. Thus observations of quasars are consistent with tidal triggering.

Bar distortions in the nuclear bulge have been suggested to feed the nucleus with disk material (e.g. Balick and Heckman 1982, Simkin et al. 1980). Strong tidal perturbations cause bars in our model so the two hypotheses do not really conflict. Feeding of the nucleus by gas from the companion (Toomre and Toomre 1972, Keel et al. 1985), requires the two galaxies to be interacting. For feeding from the companion, both galaxies probably must have gas for the "fuel" to lose kinetic energy via inelastic collisions. This is supported by Dahari's (1985) observational study of strongly interacting pairs where many spirals were Seyferts but no ellipticals were active.

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DISCUSSION

ULMER: How does tidal disruption relate to the production of the engine in the center?

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BYRD: The tidal disturbance throws some disk gas into orbits crossing the nuclear region. This gas then collides inelastically with gas in other such orbits (or with gas already in the nucleus). After a series of such collisions the gas could then be part of the accretion disk of the black-hole.

We are modest in our aims, in that we simply tabulate the amount of gas thrown into such "accretable" orbits. We do not concern ourselves with processes near the black hole. We plan future studies to model the inelastic collision process.

BOYLE: How many Seyferts in the Dahari sample show the typical perturbations that your modelling predicts?

BYRD: Dahari's 1984 work on comparative perturbations of normal spirals and Seyferts was not concerned with morphology, only separations and relative masses. However, Dahari (1985) later studied interacting pairs (which show distortions similar to those seen in our models) and found there was a higher percentage of Seyferts in the interacting than the non-interacting sample of spirals.