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ON A CONNECTION BETWEEN SUPERNOVA OCCURRENCE AND TIDAL INTERACTION IN EARLY TYPE GALAXIES

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There are three types of supernovae: two subtypes SNIa and Ib; and SNII. Late type galaxies produce all types of SN, whereas early types (E,SO, and non-Magellanic irregulars IO) have hosted only SNIa. The recently identified SNIb, like SNII, have massive stars as their progenitors.

Reviving Oemler & Tinsley's (1979) suggestion that SNIa also come from short-lived stars, we have asserted that they need not occur in all early-type galaxies. SNIa occur only in those galaxies that have access to gas and can form stars in their main body. (SN in nuclear regions are a different matter altogether). In this model, SNIa are not associated with typical stellar population of E/SOs but with regions of localized star formation. Note that data on SNIa from spirals is already consistent with this model (see Kochhar 1989 for references and details).

The fact that E, SO, and IO galaxies have so far produced only SNI implies that stars > 6-7$M_\odot$ do not form in them. It needs to be emphasized that the question before us is: what are the immediate precursors of SNIa? Their ultimate progenitors in any case are 4-7$M_\odot$ stars which leave behind a CO degenerate core, whose deflagration produces a model SNIa. If SNIa are to be associated with the typical population of E/SOs, then delayed deflagration is achieved by placing these cores in low-accretion binaries. In our model there is no delay in their deflagration so that SNIa are associated with events of recent star formation (see Kochhar 1989). The required gas in the early-type galaxies can come from a variety of sources: mergers (Fornax A, Persius A); past tidal interactions (N 5253); neighbours (N 3226). Alternatively a galaxy may accrete from its own halo (M 86) or from the intracluster medium (M 87, Coma A).

Environmental factors

If SNIa came from low-mass long-lived stars, typical of E/SOs, then the occurrence of SN would be an intrinsic property of the host galaxy, independent of galactic ecology. That this is not the case becomes immediately obvious when we consider Coma cluster. It is compact, dynamically evolved, spiral poor,.and fairly uniform in galaxy type. It shows a central maximum density and a symmetrical decrease towards the boundaries. If all galaxies were equally likely to produce SN, we would expect the supernovic E/SOs to have the same spatial distribution as the galaxies in general. This, however, is not the case. All supernovic galaxies in Coma are confined to a plane (Figure 1). The reason must be that the hot intracluster gas has settled in a central disc, and been accreted by the galaxies there. There are 8 SN in the disc, and two of the host galaxies are IO type, clearly a result of accretion.

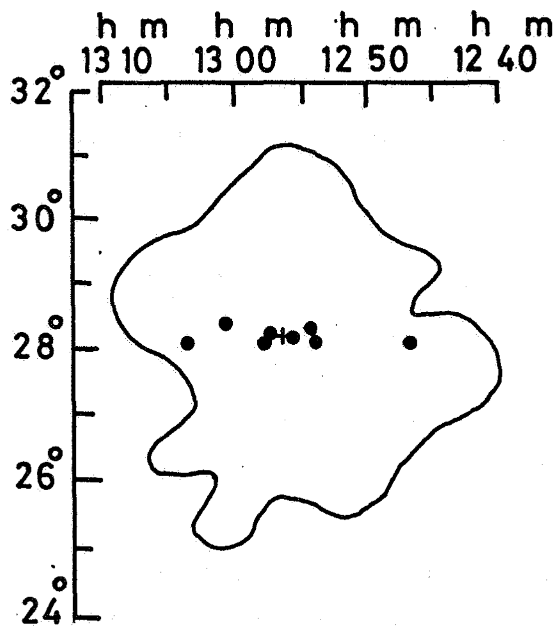

Figure 1. The supernovic galaxies in the Coma cluster (Barbon 1978).

In contrast to Coma is the Virgo cluster, in which galaxies carry their own reservoirs of gas in the form of hot halos. Although it contains only 11 % of all NGC early-type galaxies it accounts for 30 % of the supernovic E/SOs. Thus Virgo galaxies are thrice as SN prone as a general sample is. According to Tammann (1974) the effect is real and not an artifact of higher search intensity.

X-ray luminosity

The X-ray luminosity of early-type galaxies in Virgo and elsewhere can be explained by gravitational heating only if SN heating is not important. A specific model for N 4472 (Thomas 1986) requires a SN rate of 0.01 SNU, much lower than the estimates of 0.22 (Tammann 1974) or 0.07 (Evans et al. 1989). The problem is more serious than realized because if any thing Virgo SN rate is higher than the average. In our model, SN occur in regions of recent star formation. The SN energy is used in dispersing the dense gas clouds and thus does not contribute towards X-ray luminosity.

Supernovic E/SOs

IO galaxies are essentially E,SO galaxies that have been excessively contaminated by gas and dust. They all show signs of star formation and are prolific producers of SN, significantly only SNIa. Five of them have produced 8 SN: N 2968, 3656, 4753^2, 5195^2, 5253^2; superscript 2 denotes the occurrence of 2 SN. Of special interest is NGC 5253, which along with N 5102, 5128(Cen A) and 5236 constitutes Centaurus chain. Accretion of gas from a common envelope has resulted in star formation in N 5253; enhanced star formation rate in N 5236 (5 SN); fuelled the radio source in N 5128; and produced a burst of star formation 10^8 yr ago in N 5102. Three other galaxies with 2 SN underline the role of supply of gas. N 1316 (For A) has certainly swallowed one possibly many gas rich companion galaxies. N 4874 lies at the centre of Coma cluster with access to intracluster gas (see above). The non-descript MCG 5-27-53 is an SO galaxy in the Zwicky cluster 156-14. Both the SN lie on a faint ring around it. This galaxy forms a pair (Ho 244) with the barred spiral MCG 5-27-52, 2 arcmin away, which is presumably the source of gas for the supernovic galaxy.

There are 12 SO galaxies that have produced SN (N 1332, 1411, 3570, 4340, 4382, 4410, 4451, 4526, 4887, 5485, 6835, and 7634). Six of these are paired galaxies, eight carry the tag peculiar, doubtful, or uncertain in RC2 — again suggesting a connection between SN occurrence and external factors. There are 17 ellipticals that have produced SN : N 1275 (Per A), 1316 (For A), 2672, 3226, 3574, 3904, 4335, 4374 (M 84), 4406 (M 86), 4486 (M 87), 4564, 4621, 4636, 4782, 4874 (Com A), 5128 (Cen A), 7619.

M 86's SN is within its hot halo and on intergalactic bridge to M84. Four of the remaining 16 galaxies form pairs with other galaxies which can supply gas. An additional seven show hot gas which can cool to form stars. 12 out of 16 show one activity or other. Two of the remaining four (N 4564 and 4621) are in Virgo cluster. They are only two galaxies whose only claim to fame has been the SN. These four and their SN certainly deserve a second look.

One is confronted with a north-south divide while trying to correlate SN occurrence with other properties. Most supernovic galaxies are in the northern skies whereas most recent studies are of the southern. Since only complete radio samples are available, we compare in Figure 2 radio and SN activities. It can be seen that the fraction of radio emitters in a subsample of supernovic ellipticals is much higher than in the general sample. The numbers involved are small, but the trend is unmistakable. In view of the well attested correction of the radio property with the others, we conclude that SN activity is indeed related to the others.

Since SN occurrence in E/SOs requires localized star formation, integrated fixed-aperture photometry is not expected to show these galaxies to be significantly bluer than a general sample. We have started an observational program using La Palma 1 m telescope to see if regions around SN show signs of recent star formation (I.Perez Fournon & R.K.Kochhar in preparation).

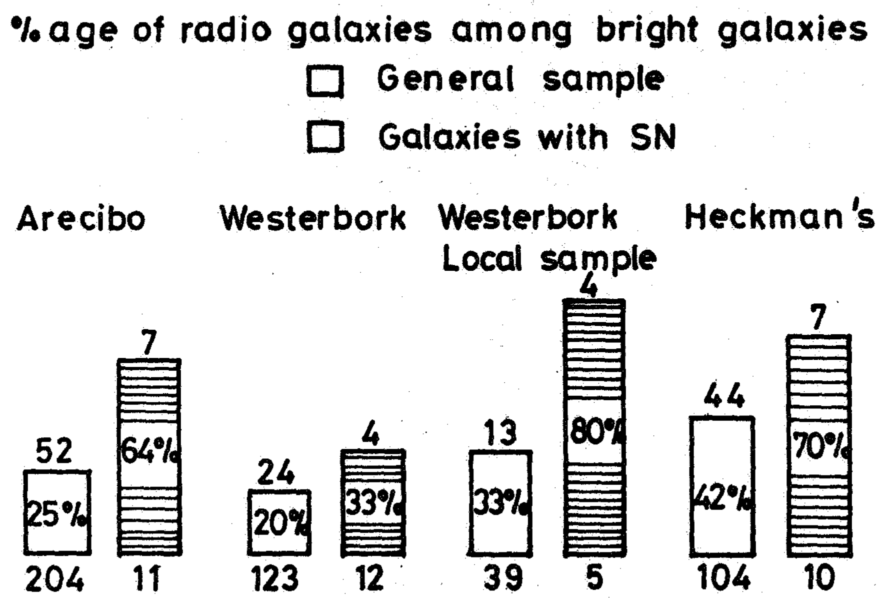

Figure 2. The percentages of radio galaxies in samples of bright galaxies and in subsamples of bright supernovic galaxies (Kochhar 1989).

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DISCUSSION

Hutchings: Can SN be detected spectroscopically in the bright inner regions of star-forming galaxies? (What is the expected SN rate for a starburst?)

Kochhar: R. Terlevich (1989, RGO preprint 100) has identified the rapid flare in spectral variability in Sy 1 galaxies N 5548, 1275, 4151, and 3516 with the SN flash. The longer term variability has been attributed to the evolution of the SN remnants. (The expected SN rate is about one per year.)