PRESENT STAR FORMATION IN SPIRALS OF THE VIRGO CLUSTER

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ABSTRACT. From a study of spiral galaxies in the Virgo Cluster (VC), it is shown that RDDO anemics with smooth arms and no sign of present formation of (massive) stars have HI surface densities below a threshold value of 2 to 5×10^{20} atom cm^{-2}. This value is very consistent with predictions of theoretical models. It is likely that the HI disks of VC HI-deficient RDDO anemics have been deeply affected by ram pressure stripping in the gaseous intracluster medium, while VC HI-deficient RDDO spirals have been only peripherally stripped.

1. RDDO ANEMICS IN THE VIRGO CLUSTER

The anemics of the RDDO classification introduced by Van den Bergh, 1976, are smooth-arms disk galaxies with no "knots" characterizing HII regions and OB associations. Consequently they have a low present star formation rate of (at least) massive stars. Since most RDDO anemics are assigned RSA type Sa (Sandage and Tammann, 1981, Bothun and Sullivan, 1980) and since they do exist in the field, anemics might be simply the normal transition stage of the Hubble sequence between spirals which actively form stars and lenticulars (Sandage, 1983). On the other hand, since rich clusters actually have a large population of smooth-arms, faint disks (Wirth and Gallagher, 1980), anemics might be a stage of the evolution of spirals after interactions with an aggressive cluster environment (Van den Bergh, 1976, Strom and Strom, 1978).

Guiderdoni and Rocca-Volmerange, 1985 (hereafter GRV), studied the observational properties of 107 spirals and irregulars (S0/a to Im, that is $0 \leq T \leq 10$ according to de Vaucouleurs et al., 1976, RC2) in the VC, from a compilation of HI and photometric data. Among this sample, 38 galaxies have a RDDO class from Van den Bergh, 1976, or Giovanardi et al., 1983: 24 are anemics (A or S0, S0/A, A ?, A/S) and 14 are normal, "healthy" spirals (S): Guiderdoni, 1986, studied the properties of these objects and some results are hereafter summarized.

2. EVIDENCE FOR A THRESHOLD IN STAR FORMATION PROCESSES

It is well known that spiral galaxies in the VC are HI-deficient relative to reference counterparts with the same RC2 morphological type and optical surface (Davies and Lewis, 1973, Chamaraux et al., 1980, GRV). The deficiency parameter is here $Def(\sigma_H) = (\langle \log \sigma_H \rangle_T - \log \sigma_H)/\sigma_T$. σ_H is the ratio of HI mass to optical surface inside the B-isophote $\mu_B = 25.0$ mag $arcsec^{-2}$ and the means $\langle \log \sigma_H \rangle_T$ and dispersions σ_T are computed in GRV at fixed RC2 morphological type T from a reference, "field" sample.

It is hereafter shown that HI-deficient RDDO spirals and anemics have different HI surface densities in the central regions of their disks. Giovanardi et

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al., 1983, gave HI diameters at 1/3 x central peak and the derived HI surface densities $\Sigma_H = M_H / \frac{\pi}{4} D_H^2$ closely approximate the HI surface densities in the central regions of the disks. For 13 anemics, $\langle \log \Sigma_H \rangle = -0.43 \pm 0.11$ ($\Sigma_H \simeq 2.2 \times 10^{20}$ atom cm^{-2}) while for 10 RDDO spirals, $\langle \log \Sigma_H \rangle = 0.26 \pm 0.06$ ($\Sigma_H \simeq 1.1 \times 10^{21}$ atom cm^{-2}). Figure 1 readily shows that the HI surface densities of RDDO spirals are always higher than those of anemics, whatever the deficiency may be. The separation value between the two RDDO classes corresponds to $\Sigma_H \simeq 6.0 \times 10^{20}$ atom cm^{-3}.

Bosma, 1981, gave HI diameter $D_{H,5}$ at the isophote 5×10^{20} atom cm^{-2}. For 17 spirals, $\langle D_{H,5}/D^o_{25} \rangle = 1.64$. Similarly, lenticulars mapped at λ 21 cm have disk column densities lower than 5×10^{20} atom cm^{-2} (Sancisi, 1983). So no formation of (at least) massive stars is expected for this value of HI surface density. Thus the global star formation is a threshold process, with a regulating parameter strongly related to Σ_H.

Two theoretical models of star formation predict the existence of such a threshold related to the HI surface density (Elmegreen, 1979 and Seiden, 1983; Dopita, 1985). Guiderdoni, 1986, showed that both models lead to numerical values of the threshold $\simeq 2$ to 5×10^{20} atom cm^{-2}, in remarkable agreement with the observational results.

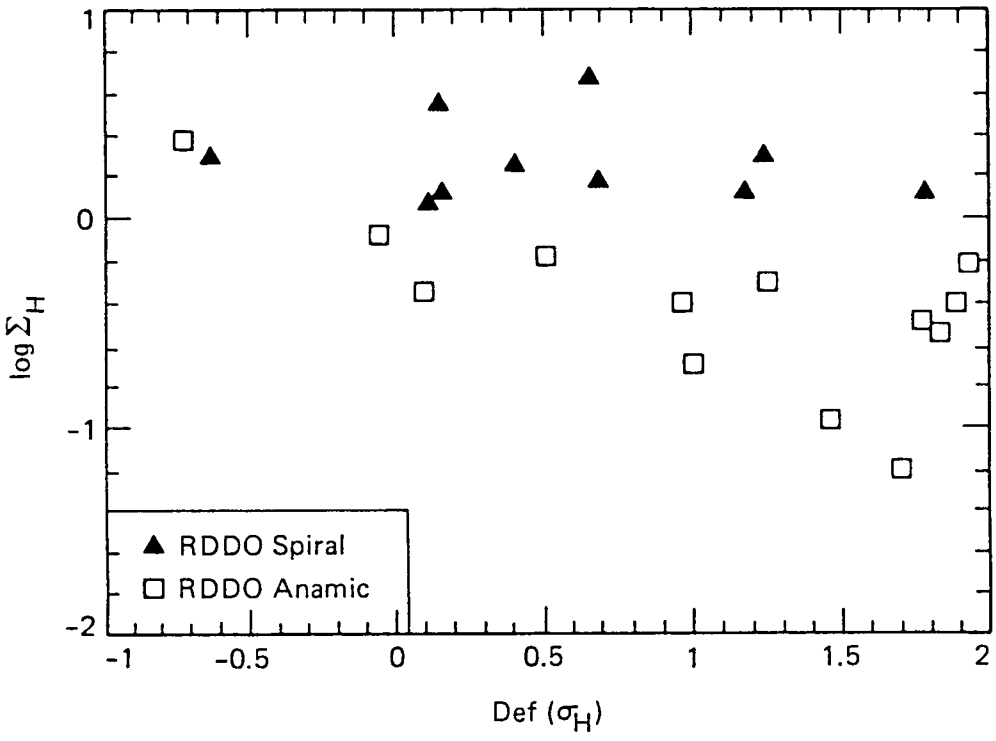

Figure 1 - HI surface density log Σ_H (in 10^{-3}g cm^{-2}) versus deficiency parameter Def(σ_H). See text for definitions. Triangles = RDDO spirals. Squares = RDDO anemics.

3. THE FATE OF SPIRAL GALAXIES IN THE VIRGO CLUSTER

There is a now good evidence that in the VC as well as in some other clusters, the HI disks are altered by ram pressure stripping (and evaporation) in the gaseous intracluster medium (see references in Guiderdoni, 1986). It appears in figure 2 that RDDO spirals and anemics have been affected by the stripping in a different way. The inner disk value log Σ_H for RDDO spirals does not depend on Def(σ_H), supporting an effective stripping only in the peripheral regions. As a matter of fact, figure 2 shows that D_H/D°_{25} well correlates with Def(σ_H). On the contrary, the inner disk value log Σ_H for anemics roughly depends on Def(σ_H) while D_H/D°_{25} does not depend on Def(σ_H). That seems to support a stripping occurring in the whole disk. So the present HI disks of VC anemics might originate from stellar ejecta or conversion of molecular gas into atomic gas.

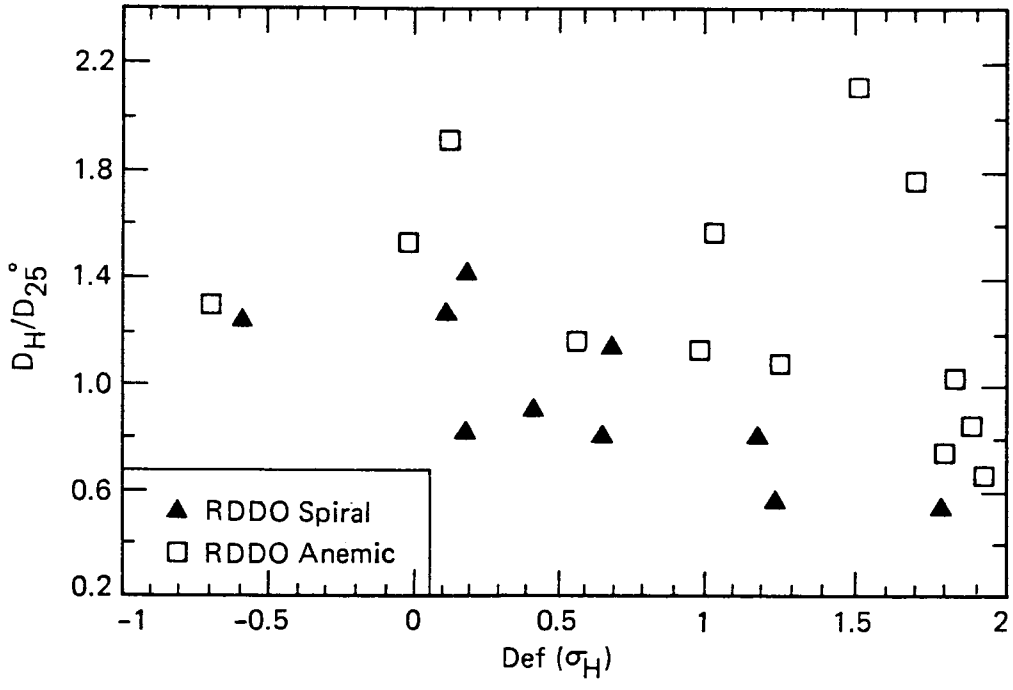

Figure 2 - HI/optical diameter ratio D_H/D°_{25} versus deficiency parameter Def(σ_H). See text for definitions. Triangles = RDDO spirals. Squares = RDDO anemics.

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