The visible environment of gas-accreting galaxies

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Abstract.

We studied the environment of a sample of galaxies in which the presence of polar rings or the presence of gas- and stars- counterrotation is observed. These galaxies are believed to have accreted this material, now in peculiar motion, from their environment.

The variable considered here are the number of possible companions in the field, down to an apparent magnitude 22, their size, their concentration around the accreting galaxy, and a set of related parameters. A control sample of 'normal' galaxies has also been studied. From Kolgomorov-Smirnov tests of the considered variables, no significant differences have been found between the population of objects around the our accreting galaxies and the control sample.

These results seems to give support to the models suggesting a long formation time for the acquisition process, starting from a diffuse gas instead of fagocitation of small satellite.

1. Introduction

The process of galaxy formation seems to continue by means of accretion of matter from the exteriors, at epochs much later than that in which a galaxy has reached a stable configuration. Peculiar morphologies and kinematical configurations such as inclined, polar or warped rings, observed in about a hundredth of galaxies (Bertola & Galletta 1978, Whitmore et al. 1990) are widely attributed to a 'second event' in the history of galaxies. The same origin is attributed to other peculiarities, such as counterrotation, a phenomenon characterized by gas and/or stars rotating in opposite direction to the most part of the galaxy (Bettoni 1984, Galletta 1987, Cirri et al. 1995). These configurations, defined by two distinct and eventually opposite spins coexisting in the same galaxies is not expected in the conventional picture of galaxy formation, driven by a sequential condensation under the effect of the gravitational force.

If there are few doubts about the external origin of the gas or stars in inclined or retrograde orbits, several different hypotheses have been presented about the origin of this matter.

On one side, the new matter has been attributed to the acquisition and engulfment of satellite galaxies, destroyed after the merging (Quinn 1991, Rix & Katz 1991). But the presence of many systems with a large amount of accreted
matter has put back this hypothesis, being a dwarf galaxy too small to justify the large detected masses in a single event of cannibalism (Richter et al. 1994, Galletta et al. 1997). In addition, the presence of accreted matter in spiral galaxies also has added the difficulty to explain the accretion of large matter in a single event without heat or destroy the disk (Barnes 1992, Rix et al. 1992, Quinn et al. 1993).

On the other side, the possibility has been studied that a large quantity of gas may be accreted by means of a progressive infall of diffuse matter (Ostriker & Binney 1989, Thakar & Ryden 1996).

In the first hypothesis (accretion of dwarf galaxies in an environment particularly rich) it is possible to detect some peculiarity of the environment by means of statistical studies in visible wavelengths of the region of sky around the gas accreting galaxies. The second hypothesis, accretion of diffuse gas, is hard to test from the point of view of statistical studies.

We started a study oriented to analyze statistically the objects present in the sky around a set of accreting galaxies, separating the polar ring galaxies from the cases of counterrotation. We present here the preliminary results.

2. Data selection and analysis

The study of the environments of these fields was based on the counts of the objects present and on the statistical analysis of their properties, such as the projected distance \( r \) from the counterrotating or polar ring galaxy and the apparent diameter \( D \) of every small, diffuse object present in the field. The positions and diameters of such objects were extracted from the APM archive (Irving et al. 1994) available at the Observatory of Edinburgh. We extracted data for the field – 200 kpc wide – of 31 polar ring galaxies (Brocca et al. 1997) and 43 counter-rotating galaxies (Galletta 1996). As control samples for each of the previous type of peculiar galaxies, we adopted a sample of 48 galaxies without polar ring and another one of 53 galaxies without counterrotation. The latter sample has been chosen looking at the published rotation curves of gas and stars of all these stellar systems, starting from the catalog published by Prugniel et al. (1998).

According to similar studies (Heckman et al. 1985, Fuentes-Wiliams & Stoke 1988) we defined for each field around the peculiar galaxy the following density parameters:

\[
\rho_{ij} = \sum_{k} r_{k}^{-1} D_{k}^{-1}
\]

where \((i,j)\) could assume the values \((0,1),(2,2)\) and \((3,2.4)\). From the above formula, \(\rho_{00}\) represent the number of neighboring galaxies, \(\rho_{01}\) is the number weighted by the relative size, \(\rho_{10}\) is weighted by proximity and \(\rho_{11}\) is weighted by size and proximity. The parameter \(\rho_{22}\) is proportional to the gravitational force exerted by the surrounding galaxies on the central object, while \(\rho_{3,2,4}\) is proportional to the tidal interaction between the surrounding galaxies and the central one. The last two parameters amplify the effects present in the parameter \(\rho_{11}\) and generally a variation of one of the above independent parameters \(\rho_{00}, \rho_{01}\) and \(\rho_{10}\) induces changes in the connected parameters.
Finally, after determining the $\rho_{ij}$ parameters for the two samples, a Kolmogorov-Smirnov test has been applied to the analyzed and the control samples by means of a Fortran program that utilizes the IMSL library routine. The results of this analysis are reported in the following Table.

Table 1. Summary of Kolgomorov-Smirnov tests. $D_\alpha$ is the maximum difference observed between the two distributions, while SL is the percentage significance level at which the two distributions compared are different.

| Parameter | $D_\alpha$ | SL (%) |
|-----------|------------|--------|
| $\rho_{00}$ | 0.14 | 10% |
| $\rho_{01}$ | 0.09 | 1% |
| $\rho_{10}$ | 0.18 | 32% |
| $\rho_{11}$ | 0.17 | 28% |
| $\rho_{22}$ | 0.19 | 37% |
| $\rho_{3,2,4}$ | 0.19 | 41% |

3. Discussion

The study of the environment based on the analysis of the $\rho_{i,j}$ parameters indicates that there are no significant, statistical differences in the optical environment of accreting galaxies (polar ring or systems with counterrotation) with respect to that of normal galaxies. None of the significance levels for the parameters is above 89%. This result is achieved also separating the sample according
to the type of the central galaxy (Elliptical, S0 or Spiral) or according to the kind of counterrotation present (gas vs. stars or stars vs. stars).

Our data suggest that the event of accretion generating the polar ring or the counterrotation has not left clear, detectable traces in the present. According to the models existing in the literature and as said in the introduction, two hypotheses may hold: 1) The accreted matter is not related to the presence of satellites and derives from a slow, non-traumatic gas infall; 2) The polar rings or the counterrotation was generated by a mass transfer from a companion galaxy or by a satellite ingestion, which is happened in a remote epoch leaving traces no longer visible inside and around the galaxies.

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