Dynamics of the Pavo-Indus and Grus Clouds of Galaxies

P. FOUQUÉ[1,2], D. PROUST[1], H. QUINTANA[2] and R. RAMIREZ[2]

[1]Observatoire de Paris-Meudon, France; [2]Pontificia Universidad Católica, Grupo de Astrofísica, Santiago, Chile

1. Introduction

One of the outstanding problems in astrophysics concerns the missing mass of the Universe: 90 % of the mass of the Universe appears to be invisible. Several arguments show that luminous mass cannot give account of dynamical effects. One of these is the high mass-to-luminosity ratio usually found in groups and clusters of galaxies.

These ratios are computed assuming that groups of galaxies are virialized entities. The actual mass of not yet virialized bound aggregates of galaxies is probably of the same order of magnitude as the mass calculated assuming that the group is virialized, but the precise ratio is unpredictable. Evidence that groups of galaxies, and at least some clusters, have not yet reached a virialized status, is growing. The time to reach virialization is larger than the age of the Universe, for many observed systems. Moreover, many clusters of galaxies show subcondensations, which might be accreted small groups not yet well mixed with the remaining galaxies of the cluster. These results force us to look more closely for truly virialized aggregates, in order to see whether these contain missing mass or not.

In order to search for such entities, we recently compiled a catalogue of groups of galaxies within 80 Mpc ($H_0 = 75$ km $s^{-1}Mpc^{-1}$) Fouqué et al. 1992) using a revised hierarchical algorithm described in Gourgoulhon et al. (1992). Our whole sky catalogue used a sample limited to a diameter of 100 arcsec, roughly corresponding to a limiting magnitude of 14. A group is recognized as such only if it contains at least three members. Therefore, groups at moderate distances were missed due to the limited depth of the whole sample.

2. The Sample

We decided to investigate selected regions by using deeper samples. The present work deals with one of such regions, where de Vaucouleurs (1975) identified two clouds of galaxies, namely Pavo-Indus and Grus. These clouds belong to the connection between the Indus Supercluster and our Local Supercluster.

Within very defined limits in these clouds, we selected from the PGC catalogue of galaxies (Paturel et al. 1989a, 1989b) all objects with a listed magnitude brighter than 15. After correction for extinction effects, the limiting magnitude becomes 14.5. Moreover, we added to the sample a few galaxies fainter than our limit, but with a known recession velocity. The total samples for the Pavo-Indus and Grus regions are 142 and 136, respectively; 58 galaxies have no known redshift.

3. Observations

The spectroscopic observations were conducted at La Silla (Chile) in September 1991 at the 1.52-m telescope, equipped with the Boller an Chivens spectrograph at its Cassegrain focus. A 600 lines/mm grating, blazed at 4500 Å in the first order, was used. The dispersion was 127 Å/mm. The detector was an excellent 1024×1024 Thomson 1K coated CCD, with a pixel size of 19 μm. The slit width was set at 2 arcsec, giving a projected slit-width of 2 pixels, and a resolution of 4.7 Å. The spectral coverage was 4250 Å to 6710 Å. Before each science exposure, a calibration with a He-Ar lamp was made. Well-exposed radial-velocity standard stars and well-known galaxies were also observed as templates in the cross-correlation procedure in order to derive the radial velocity.

The spectral reduction was carried out using the IHAP image processing software at ESO-Garching, and the recession velocities were derived from a cross-correlation procedure developed at Paris Observatory, within the frame of the MIDAS context. Figure 1 shows a histogram of the velocities for the 266 galaxies measured.

4. The Results

Although our sample is deeper by about 1 mag than the all-sky sample used in Fouqué et al. (1992), only 8 among 58 newly measured galaxies are found to belong to the Pavo-Indus-Grus groups. The remaining ones belong to the background. The limiting recession velocity, up to which our results are credible corresponds to $V_{lim} = 8{,}600$ km s^{-1} for our limiting magnitude 15 (Gourgoulhon et al. 1992). A group at that distance needs three such galaxies to be detected. As there is no galaxy in our sample with recession velocities between 7,060 and 7,849 km s^{-1} (see Fig. 1), we prefer setting the limit at 7,500 km s^{-1}, corresponding to 100 Mpc. Another hole in the distribution of recession velocities exists be-

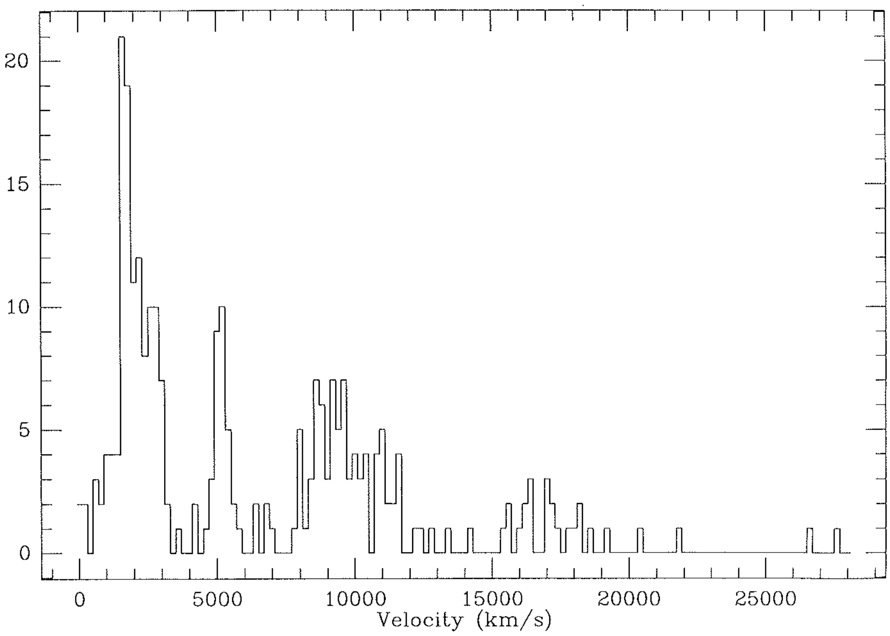

Figure 1: *Histogram of heliocentric velocities of the 266 measured galaxies. Holes around 3,500 and 7,500 km s^{-1} are noticeable.*

Table 1: *M/L ratio for the 6 most populated groups (see text)*

Group name	N	σ_V	$\left(\frac{M_V^w}{L}\right)_{obs}$	$\left\langle\frac{M_{sim}}{M_{obs}}\right\rangle$	σ	M_P/M_V^{uw}	M_A/M_V^{uw}	M_M/M_V^{uw}
NGC 7582	11	121^{+40}_{-21}	5– 15	6.84	3.42	2.29	1.60	0.89
NGC 7213	9	144^{+61}_{-36}	35–158	1.69	1.07	3.05	2.56	2.09
NGC 7060	6	157^{+90}_{-38}	37–205	0.90	0.26	1.80	1.26	1.40
IC 1459	11	120^{+40}_{-22}	53–167	1.18	0.44	1.63	0.83	1.07
NGC 7079	9	98^{+42}_{-26}	58–284	0.82	0.26	1.42	1.14	1.35
NGC 7424	7	175^{+84}_{-34}	214–892	1.31	0.55	1.64	1.45	1.70

tween 3,196 and 3,629 km s^{-1}. We are therefore rather confident of the completeness of our list of groups up to 3,500 km s^{-1}.

Using the same hierarchical algorithm as in Gourgoulhon et al. (1992), we find 18 groups, containing 95 galaxies among the 160 with V < 7,500 km s^{-1} (59 %). 18 other galaxies belong to pairs, and 19 are isolated members of associations (regions where the density level is five times less than for groups). This leaves 28 apparently isolated galaxies. In fact, two of them probably belong to the Local Group and the Sculptor Group, and 13 of them have a recession velocity larger than 3,500 km s^{-1}.

Most of the detected groups were already known. Two new associations are evidenced below 3,500 km s^{-1}. Only one association is detected between 3,500 an 7,500 km s^{-1}, which contains four groups. The median line-of-sight luminosity-weighted velocity dispersion is 90 km s^{-1}, part of which is due to the measurement uncertainty. The median virial radius is 0.53 Mpc. The median mass-to-blue luminosity ratio is 75 $M_\odot/L_\odot$. The median crossing time is 2.0 × 10^9 yr, showing that our aggregates are gravitationally bound entities and not spurious concentrations.

Figure 2 shows the projected distribution of the galaxies in our sample. Group members are identified by special symbols. Figure 3 shows an iso-number density plot of the 122 galaxies with recession velocities smaller than 3,500 km s^{-1}; the four most luminous groups are evidenced.

5. Discussion

Our main goal, when we embarked upon this survey, was to understand the large dispersion observed in the M/L ratios of the groups in our all-sky survey, and to determine if certain parameters can help to understand this dispersion. Our present deeper survey has not reduced the dispersion, with M/L values varying between 9 and 442 $M_\odot/L_\odot$. If we now restrict the discussion to groups

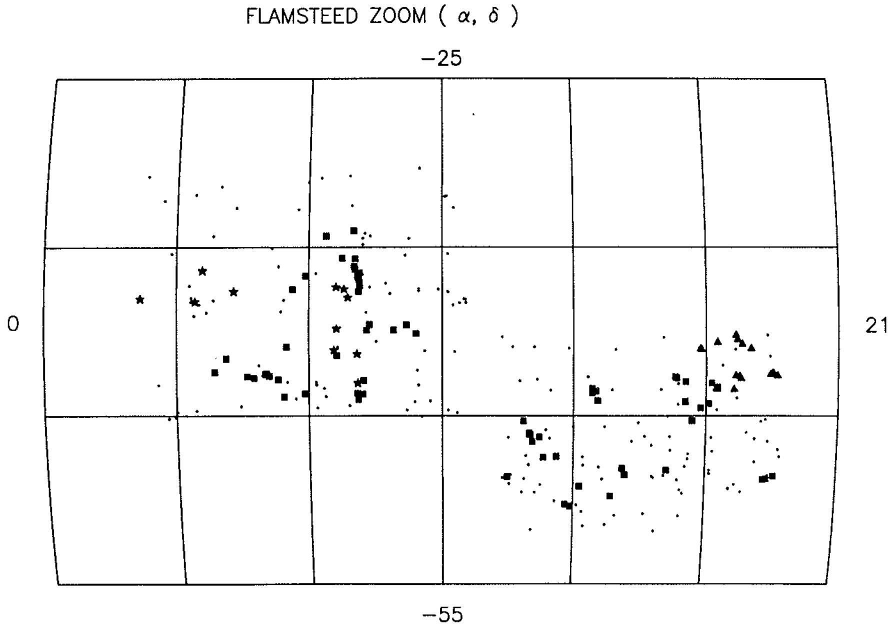

Figure 2: *Projected distribution of the 278 galaxies, in a sinusoidal (Flamsteed) projection. Filled symbols represent members of the 18 groups (stars if V < 1,500 s^{-1}, squares if 1,500 < V < 3,500 km s^{-1}, and triangles if 3,500 < V < 7500 km s^{-1}). Dots represent galaxies not assigned to groups, or galaxies with V > 7,500 km s^{-1}.*

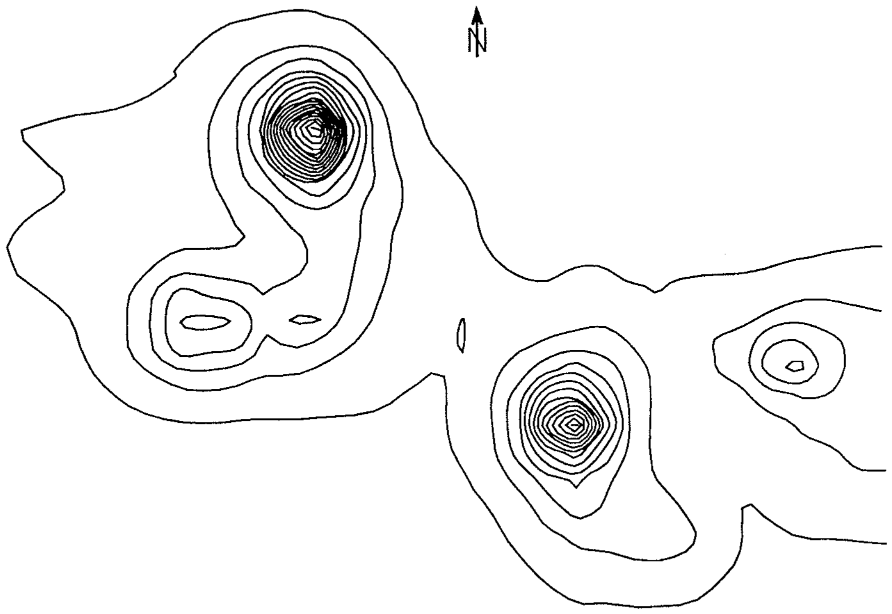

Figure 3: *Iso-number density plot of galaxies with recession velocities smaller than 3,500 km s^{-1}. North is up and east at left. The lowest contour corresponds to 1 galaxy per Mpc^2, and an interval corresponds to 1 galaxy per Mpc^2. The peak is at 18 galaxies per Mpc^2.*

with at least 5 galaxies, to reduce effects of projection factors and poor statistics, we get 6 groups, which we will compare in more detail.

The uncertainty of our M/L estimate depends upon both mass and luminosity errors. As our estimate of L involves correcting factors for incompleteness, it is difficult to estimate an error bar. We therefore concentrate our effort on mass determination, in three directions: we first correct the dispersion velocity for measurement uncertainties, using the precepts of Danese et al. (1980). The result is given in columns 3 and 4 of Table 1.

Then, we make a simulation keeping fixed the positions on the sky of the galaxies in a group, but mixing their velocities and their luminosities, choosing at random 1,000 possibilities among the ($N!^2$) combinations, and computing a new M/L ratio. We than compare it to the observed M/L, and compute the ratio of both numbers. The mean value of the 1,000 trials and their rms dispersion are given in columns 5 and 6 of Table 1. An average value significantly different from one implies that the observed configuration is rather particular. This is the case of the NGC 7582 group, which has the lowest observed M/L ratio. On the other hand, the highest M/L ratio, observed in the NGC 7424 group, is confirmed by our simulation. In fact, the mean ratio M_{sim}/M_{obs} is a measure of the ratio unweighted over weighted estimators of the virial mass.

Finally, we compute the Heisler et al. (1985) estimators of mass, and compare them to the virial mass. The projected mass is computed assuming isotropic orbits and equal masses. The ratios of projected mass, average mass and median mass over unweighted virial mass are given in columns 7, 8 and 9 of Table 1.

6. Conclusions

Several conclusions can be drawn from the results of Table 1, being aware that our statistical basis is very limited.

The low observed M/L ratio of the NGC 7582 group appears to be due to a particular configuration of the galaxies. The unweighted virial mass to luminosity ratio is well within the range of other groups.

The high values of the ratios M_P/M_V^{uw}, M_A/M_V^{uw} and M_M/M_V^{uw} of the NGC 7213 group are probably due to the violation of one underlying hypothesis made to compute these masses, namely that the galaxies in the group have equal masses. Remember that for a group dominated by a massive central member, the *projected mass estimator* is divided by two.

The ratio M_p/M_V^{uw} appears to be larger than the two other ratios, M_A/M_V^{uw} and M_M/M_V^{uw} : the mean value for projected masses is about 2, while it is about 1.5 for average and median masses. This possibly corresponds to an intermediate situation between equal masses and dominant central galaxy (see previous point). An average coefficient between these two extreme cases would give M_P values lower by a multiplicative factor 0.75, and this would put the three ratios at the same level. However, this common level still corresponds to masses 50% higher than the unweighted virial mass.

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Phase-A Study Launched for the 10/20-μm Camera/Spectrometer for ESO's VLT

On March 9, 1993 the kick-off meeting for the Phase-A study for the Mid-Infrared Imager/Spectrometer was held at ESO Headquarters. The instrument to be studied will be mounted at the Cassegrain focus of the VLT unit telescope No. 2. It is planned to have this instrument manufactured outside ESO. Shortly summarized, the instrument should provide for direct imaging with various filters and long-slit spectroscopy with $\frac{\lambda}{\Delta\lambda} \approx 300$, 8,000 and 30,000–50,000 for the 10-μm atmospheric window and some limited access to the 20-μm atmospheric window.

This kick-off meeting was preceded by a study phase inside ESO to define the overall scope of the project and to lay out a potential embodiment of such an instrument[1]. In 1992 ESO sent out a preliminary inquiry to 30 institutions in ESO member states in order to identify and select institutes interested and competent to design and manufacture such an instrument including installation and commissioning at the VLT observatory. As a result, ESO selected DAPNIA/CE-Saclay from France as contractor heading a consortium for a phase-A study. A contract was negotiated and signed in March 1993. The consortium is headed by P.O. Lagage. Partners for the study are SRON, Groningen (T. de Graauw), the Kapteyn Sterrenwacht, Roden (J.W. Pel) both from the Netherlands and the IAS-Orsay, France (R. Gispert).

It is the objective of this study to provide for:

- a preliminary design of the optics, cryogenics, vacuum system and electronics for a system which could fulfil ESO's basic requirements,
- a critical review of the detector situation,
- a performance estimate including the effects of the Earth's atmosphere,
- a predesign of any calibration/test facilities required,
- a detailed cost estimate,
- a description of the scientific objectives the scientists involved in the study expect to address with the instrument in their guaranteed observing time (which they will receive as a compensation for their effort).

In addition the consortium can study alternative technical concepts and scientific operation modes to the extent they deem appropriate.

It is planned that the study will be finished after 18 months. ESO intends thereafter to negotiate a contract with DAPNIA/CE-Saclay for the actual manufacture, installation and commissioning of that instrument.

H. U. KÄUFL, ESO

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[1] The result of these internal studies is described in greater detail in H.U. Käufl & B. Delabre, 1992, "Design of a 10/20-μm Camera/Spectrometer for ESO's VLT" in Proc. ESO Conference on Progress in Telescope and Instrumentation Technologies, p. 597, ed. M.-H. Ulrich.