329. P.A. Shaver: Clustering at High Redshifts. To appear in "Inner Space/Outer Space", proceedings of a conference held at Fermilab, 2–5 May 1984 (University of Chicago Press. June 1984).
330. M.-P. Véron-Cetty: Study of a Complete Sample of Galaxies. I. UBV Aperture Photometry. *Astronomy and Astrophysics Suppl.* June 1984.
331. B. Reipurth and P. Bouchet: Star Formation in Bok Globules and Low-Mass Clouds. II. A Collimated Flow in the Horsehead. *Astronomy and Astrophysics*, Letters. July 1984.
332. B. Barbanis: The Stochastic Behaviour of a Galactic Model Dynamical System. *Celestial Mechanics.* July 1984.
333. L. Maraschi et al.: Coordinated UV and Optical Observations of the AM-Her Object E 1405–451 in High and Low State. *Astrophysical Journal.* July 1984.
334. E.A. Valentijn and A.F.M. Moorwood: The Stellar Content of the A 496 cD Galaxy. *Astronomy and Astrophysics.* July 1984.
335. A.C. Danks and J. Materne: The Galaxy Group Klemola 25. *Astronomy and Astrophysics.* July 1984.
336. S.R. Federman, A.C. Danks and D.L. Lambert: The CN Radical in Diffuse Interstellar Clouds. *Astrophysical Journal.* July 1984.
337. S. D'Odorico, R.G. Gratton and D. Ponz: A High Dispersion Analysis of a Giant Star in 47 Tucanae. *Astronomy and Astrophysics.* August 1984.
338. F. Matteucci and A. Tornambé: Carbon Deflagrating Supernovae and the Chemical History of the Solar Neighbourhood. *Astronomy and Astrophysics.* August 1984.
339. C. Barbieri, S. Cristiani, S. Omizzolo and G. Romano: The Variable Extragalactic Object 3C 446. *Astronomy and Astrophysics.* August 1984.

Rotation Axes of Gas and Stars in Elliptical Galaxies

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Recent studies (1, 2) of the distribution and kinematics of gas in elliptical galaxies have revealed that in most cases there is no correlation between the position angle of the major axis of the gas and that of the stellar isophotes. In addition, a decoupling is present in the kinematical axes of these components, in that the kinematical major axes of gas and stars do not coincide.

But until now a comparative study of gaseous and stellar dynamics has been made for only very few of these systems; in the past only the stellar or only the gaseous dynamics have been studied in detail. In order to extend this study to a wider sample of objects, it is necessary to have simultaneously the kinematical properties of both gas and stars.

For this purpose we started observations in March and in May 1983 and in March 1984 with the image tube + B & C spectrograph attached to the 1.52 m and 3.6 m ESO telescopes with dispersion of 29 and 39 Å/mm, in order to obtain a complete velocity field for 6 elliptical galaxies, listed in Table 1.

TABLE 1

NGC	Type	M_{B_T}	P.A. kin. maj. axis Stars	Gas	σ_o (Km sec^{-1})	V_m/σ_o
2325	E4	− 21.01	6° (maj. ax.)	–	181 ± 12	0.31
2974	E4	− 21.01	45° (maj. ax.)	45° (maj. ax.)	221 ± 30	0.83
3962	E1	− 20.91	0° (maj. ax.)	90° (min. ax.)	240 ± 50	0.27
5077	E3 +	− 21.05	7°? (maj. ax.)	97° (min. ax.)	307 ± 50	0.095
5846	EO +	− 21.22	4°?	90°	244 ± 26	0.25
5898	EO	− 20.54	150°	150°	174 ± 40	0.3

The spectra were digitized with the ESO PDS microdensitometer with an aperture of 12.5 μ × 50 μ. All the spectra were calibrated in intensity and wavelength using the IHAP system of Garching. All the calibrated spectra were finally analysed with the Fourier Quotient Method of the Padova Observatory computer centre in the spectral range λλ 3900–4500 Å. This method allowed us to obtain simultaneously the radial velocity V_r, the velocity dispersion σ and the line strength γ for each position angle (P.A.) observed. The emission lines were measured with the ESO Grant machine and the data were reduced at the Padova Observatory computer centre. An additional measurement of redshift and FWHM of emission lines has been performed by using a non interactive batch IHAP programme, the result being in good agreement with the Grant measurements.

In Table 1 we list the galaxies observed, their morphological characteristics (3) and the distances, obtained from the redshift, assuming H_o = 50 km sec^{-1} Mpc^{-1}. We report also the dynamical behaviour, i.e. the position angle of maximum rotation, for stars and gas, estimated by means of cosinusoidal interpolation of the central velocity gradients versus P.A., and the value of V_m/σ_o observed for the central regions. The error in the P.A. of the line of nodes obtained by this procedure is about 10°. All the galaxies follow with little scatter the $L \propto \sigma^4$ (4) and the log (V_m/σ_o)vs M_B (5) relations for elliptical galaxies.

Despite these common morphological and kinematical properties, the galaxies considered show many differences concerning the internal dynamics of gas and stars. All but one case show that gas and stars have different rotation axes, which in most cases are nearly perpendicular.

NGC 2974 is the only galaxy in which gas and stars share the same velocity trend along all the position angles observed. In Fig. 1a, b are shown the rotation curves along the major and minor axis respectively. The gas seems to be in a disk with the line of nodes coincident with the major axis of the stellar component, in agreement with previous observations (2). The same behaviour is exhibited by the stars. The representative point of NGC 2974 in the V_m/σ_o-ε diagram falls exactly on the line of oblate isotropic rotation, a fact which, together with the previously cited gas and stars spin axes alignment, implies that this galaxy is very similar to a fast spinning disk of stars.

NGC 5077, on the other hand, is a system where the stars do not show appreciable rotation, while the gas, more extended along the apparent minor axis of the galaxy, shows along this axis a well defined rotation curve (Fig. 2a, b). This behaviour resembles the visible configuration observed in NGC 5128, where the dust lane represents a disk rapidly rotating with the spin axis aligned with the major axis of the stellar body (6).

This interpretation is confirmed by the low value of V_m/σ_o for the stars which places this bright galaxy (M = −21.1) among the low rotators and well down the predicted line of prolate figures. These two properties suggest that this galaxy repre-

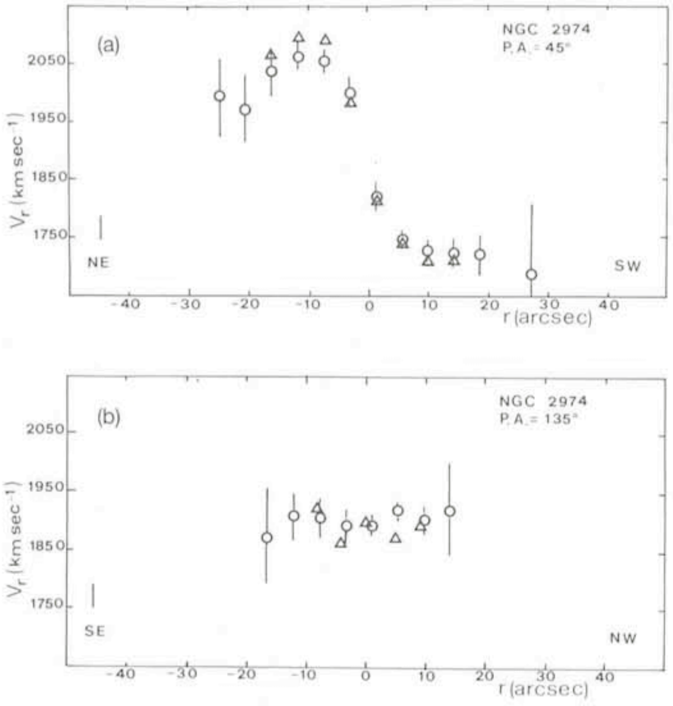

Fig. 1: *Rotation curves of NGC 2974 along the major (a) and minor (b) axes for gas (Δ) and stars (○). The error bars for the rotation curve of the stars are from the Fourier Quotient Method. The mean error for the Grant measurements of emission lines (30 km sec^{-1}), is indicated by a bar at the lower left of the diagrams. (The data are from two 60^m exposure spectra from the ESO 1.5 m telescope.)*

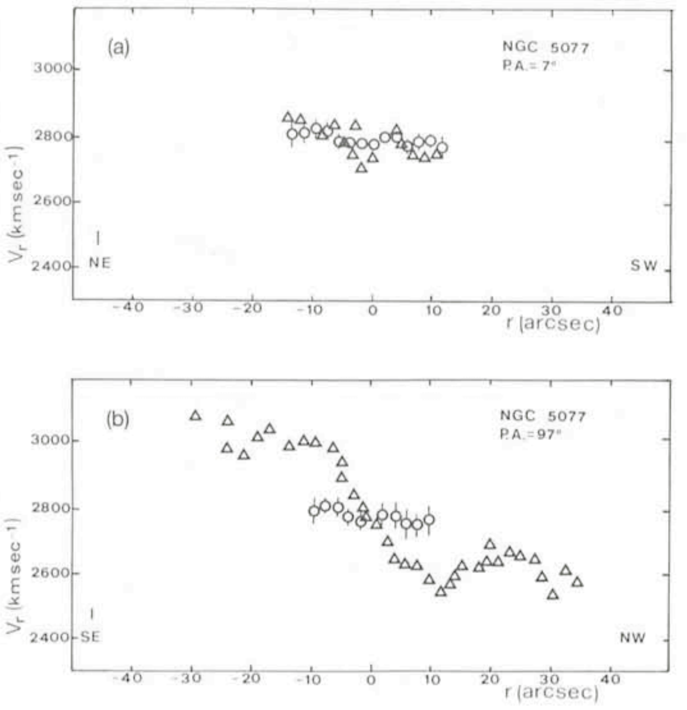

Fig. 2: *Same as Fig. 1 but for NGC 5077 along the major (a) and minor (b) axis. (The data are from two 90^m exposure spectra from the ESO 3.6 m telescope.)*

sents a case in which the gas disk, even though not obscuring the stellar body, lies in the equatorial plane of a prolate or almost prolate galaxy.

NGC 3962 is rounder than NGC 5077 but shows the same kinematical characteristics. The stars have the maximum velocity gradient along the apparent major axis while the gas, also in agreement with previous observations (2), reaches the maximum rotation along an axis which is nearer to the optical minor axis. This fact, together with the low value of V_m/σ_o, suggests, again like NGC 5077, that the gravitational potential in NGC 3962 is nearly prolate.

In the flattened galaxy NGC 2325 (E4) the stars do not seem to rotate appreciably, although a slight tendency to rotation appears along the apparent major axis. On the contrary, no rotation is detected for the gas in the two P.A. studied (major and minor axis). Since we expect that, because of dissipational processes, the gas lies in a flattened disk, the absence of rotation within $|\Delta V| = 50$ km sec^{-1}, suggests that we are viewing the gas disk almost face-on.

The two remaining galaxies are both of EO type, but from the comparison of gas and stellar kinematics we can deduce that we are looking at two very different systems.

Our data, together with that of Ulrich et al. (2), suggest that the disk of gas in NGC 5846 is rotating along P.A. = 90°. For the stellar component our data, together with that of Peterson (7), suggest that a small velocity gradient could be present along P.A. = 4°, again a case in which stars and gas reach the maximum rotation along axes which are nearly perpendicular. In that galaxy it is also interesting to note that the velocity dispersion profile shows a strong decrease with radius. The low value of V_m/σ_o is not surprising if this galaxy is an axisymmetric system seen near to, but not exactly along, the symmetry axis (prolate or oblate). In both cases the rotation cannot be stable and the stellar gradient represents only the projection of the rotation along the line of nodes.

The other galaxy, NGC 5898, was selected from the list of objects in which Caldwell (8) recently indicated the presence of emission lines in the central regions. Stars and gas show the maximum velocity gradient along nearly the same position angle but they are rotating in opposite senses. Again these properties could be explained if the gas had been acquired from the external regions and has not yet settled to a stable configuration.

In this small sample of elliptical galaxies with nuclear emission lines, we are surprised to detect so great a difference in the dynamics of gas and stars. The fact that in most cases there is no correlation between stellar and gaseous kinematical axes strongly suggests that the gas has been acquired from outside. In this hypothesis, if the mass of gas is negligible with respect to the total galaxy mass, its motion will be determined by the gravitational potential of the stellar body only. We know that the rotation axis of the gas disk spinning within an ellipsoidal potential should align, in a short time scale, with one of the principal axes of the ellipsoid. Different configurations are expected as the galaxy tends to be more prolate or oblate. In the first case the rotation axis coincides with the major one while in the second case it aligns with the minor axis. In the more general case of a triaxial ellipsoid the spin axis could align with the major or minor axis of the configuration depending on the infall angle within the system. Then the relative positions of the gas and stars rotation axes are different for different galaxy shapes.

The wide variety of orientations found leaves open the possibility, in the light of recent theoretical work, that all of the intrinsic shapes are possible. In fact the coincidence of gas and stars kinematical position angles in NGC 2974 suggests that in this galaxy the potential is nearly oblate. On the contrary the case of NGC 5077 cannot be interpreted in this way but is better understood as an almost prolate system.

These are two extreme cases but from these results we learn that the study of the properties of the gas in elliptical galaxies is important not only to understand its origin, but also as a new interesting way for the comprehension of the intrinsic structure of elliptical galaxies.

References

(1) Bertola, F., Bettoni, D., Rusconi, L. and Sedmak, G., 1984, *A.J.*, **89,** 356.
(2) Ulrich, M.H., Butcher, H. and Boksenberg, A., 1984, ESO Preprint No. 327.
(3) de Vaucouleurs, G., de Vaucouleurs, A. and Corwin, H.G., 1976, *Second Reference Catalogue of Bright Galaxies* (University of Texas Press).
(4) Faber, S.M. and Jackson, R.E., 1976, *Ap. J.*, **204,** 668.
(5) Davies, R.L., Efstathiou, G., Fall, S.M., Illingworth, G. and Schechter, P.L., 1983, *Ap. J.*, **266,** 41.
(6) Graham, J.A., 1979, *Ap. J.*, **232,** 60.
(7) Peterson, C.J., 1978, *Ap. J.*, **222,** 84.
(8) Caldwell, N., 1984, Ph.D. Thesis Yale University.

Suspected Rotation of an X-ray Cluster of Galaxies

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Introduction

The universe as we observe it shows structure on many scale lengths. They start probably with the sizes of quarks having an extent of maybe 10^{-18} m and increase up to at least superclusters of galaxies with sizes of 10^{24} m. The building blocks of the large scale structure of the universe are, however, the largest gravitationally bound stellar systems, the galaxies. They are the largest systems we can observe relatively easily as whole objects.

The distribution of galaxies in the universe, that is in space, is difficult to determine. We can observe directly only very limited properties: distribution on the sky and, with a great effort, radial velocities. The third dimension, the distance, is normally lacking. Generally we replace it by the radial velocity. If we assume that the universe is expanding homogeneously – and there is no reason not to believe in this – we can convert radial velocities into distances using the Hubble law, radial velocities v_{rad} being proportional to distances D:

$$V_{rad} = H_o D.$$

But there is a problem. Clusters of galaxies are gravitationally bound and probably relaxed. Consequently, the internal motion of the galaxies relative to the cluster centre is superimposed onto the receding motion due to the expanding universe. The Hubble flow appears distorted in the direction of clusters.

Cluster Kinematics and Dynamics

This seeming disadvantage can also be turned into an advantage. If we have some coarse ideas about the distribution of galaxies in clusters we can identify the member galaxies using a distribution function. The simplest approach is density enhancement relative to the neighbourhood and clustering in velocity distribution. Then we can define the cluster averages and investigate the behaviour of the member galaxies relative to the cluster mean. Of course, this is an iterative process and we hope that it converges to the right model.

Apart from the galaxy distribution, the X-ray emission provides an independent way of studying cluster properties. One of our main goals is to unify observations in the optical regime with the ones in the X-ray regime. The spatial form and the gravitational potential of a cluster are very well given by the X-ray emission, the dynamics can be studied best with the galaxy velocities. A simple first step is to look for correlations of the X-ray emission with other properties: total luminosity, total mass (which should be correlated to the luminosity via a mass-to-light ratio), velocity dispersion (which should be governed by the mass distribution), content in types, or cluster classification.

Therefore, many astronomers started to observe in more detail clusters which were detected by the satellites Uhuru or Ariel as X-ray sources.

An ultimate aim is to understand the phase space distribution function of the galaxies in clusters. Then we would know at each place the density of galaxies and their velocities. When using the galaxy distribution combined with the X-ray emission distribution, we have to be very careful because the dynamical age of these components may be different. An important question is whether the galaxies and the hot gas are formed together or if the galaxies have shed the gas during their lifetime into the intracluster space. The latter assumption is more plausible because the X-ray emitting gas seems to be processed material, matter which has gone through stars already and which is enriched with heavy elements.

The Cluster SC 0316-44

One of the galaxy clusters discovered with the Ariel satellite is in the southern hemisphere (03^h16^m–44°). One of the first investigations of this cluster was done by the two former ESO members J. Melnick and H. Quintana. They noted some curious properties of the cluster:

(i) SC 0316-44 has a very large velocity dispersion. The radial velocities scatter over a broad range.

(ii) It belongs to the few clusters in which the central dominant cD galaxy (number 18 in the figures) is neither at the dynamical centre of the cluster nor at the bottom of the potential well. In the present case the most massive galaxy does not have the mean radial velocity though it is roughly in the geometrical centre.

(iii) It has a dominant cD galaxy. But there is also a galaxy nearly as big as the central one, far offset from the centre (number 8 in the figures). One might speculate that we have in reality two clusters centred on these two dominant galaxies.

This made the cluster interesting enough to investigate it again. We counted and determined the positions of all the galaxies with a major diameter larger than 14 kpc in the region of the cluster. For comparison, our Galaxy has a major diameter of some 30 kpc. The measurements were done with the ESO Optronics machine in Garching. The positions were measured manually but the software available made these measurements very efficient. There were nearly 1,100 galaxies. Their spatial density distribution projected on the sky reveals another remarkable fact:

(iv) The central part of the cluster is elongated in the NE-SW direction. The outer regions indicate, however, an elongation in the NW-SE direction though this is still a matter under discussion. Elongation of clusters is not so unusual. The Basel