staff astronomers and skillful night assistants on La Silla.

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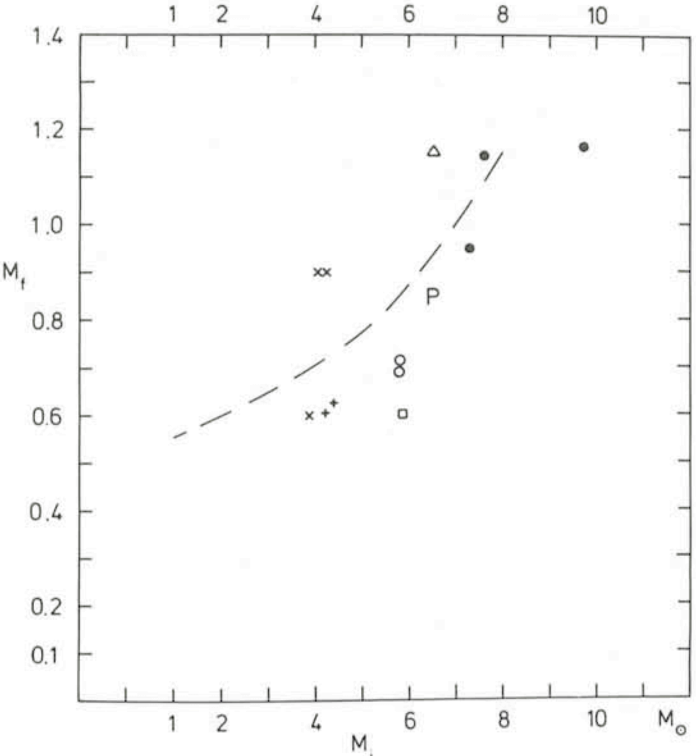

Figure 3: *Initial-final mass relation for intermediate-mass stars according to cluster white dwarfs identified in the course of this programme. Symbols: ○ NGC 2516, + NGC 2287, x NGC 3532, ° NGC 2168, □ NGC 2451, △ NGC 6405, P Pleiades. The broken line is the relation adopted by Weidemann (1987).*

New Results About SB0 Galaxies

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We discuss here the preliminary results of a long term project on kinematics and photometry of SB0 galaxies begun at ESO in 1983 and not yet fully completed. Beginning this study, we were particularly interested in analysing the mark of triaxiality that the bar induces in otherwise symmetrical galaxies, by perturbing and stretching out the stellar orbits. But we did not imagine that, progressing in this almost unexplored land, so many new and not yet fully explained features would be discovered. Now, we feel it would be interesting to resume here before the completion of the search the main results so far obtained.

1. A Bit of History

SB0 galaxies are good candidates for this study because of the low, but not negligible, quantity of gas and dust present in them. But despite the large number of theoretical models of bars, and the several works on gas kinematics, stellar motions were in the past very little studied. A systematic attempt to analyse the kinematics of SB0s (Kormendy 1982, 1983) was never completed and practically only one galaxy, NGC 936 (Kormendy 1983, 1984), was studied in detail (photometry, stellar velocity field and velocity dispersion field) before 1987. Similar projects at other observatories followed the same course, with observations never completed or results never published. Probable reasons for this were the difficulty of supporting for many years a project requiring many observing nights against the idea that in the melting pot of billions of stars moving within the bar it should be impossible to distinguish between "families" of orbits and, last but not least, against the occasional misunderstanding of some (too human) time commissions. But with some vicissitudes and a little bit of luck, observations of SB0s continued at ESO telescopes, demonstrating that we can look inside the stellar and gas kinematics with good hope of progressing toward its complete understanding. In recent years, therefore, new data on stellar kinematics have become available for eight more SB0s (Galletta 1987, Bettoni and Galletta 1988, Bettoni et al. 1988, Jarvis et al. 1988, Bettoni 1988). The observational techniques used in our observations reflect the improvement of ESO instrumentation in these years: starting with the 3.6-m telescope with the Boller & Chivens spectrograph and the 3-stage EMI image tube, the observations continued at the ESO-MPI 2.2-m telescope with RCA CCDs when these detectors became available. Parallel to this study, the inner photometry of the selected galaxies has been performed using the ESO-Danish 1.52-m telescope.

2. Observations and Data Reduction

Our sample includes 15 SB0 galaxies brighter than the 12[th] magnitude and

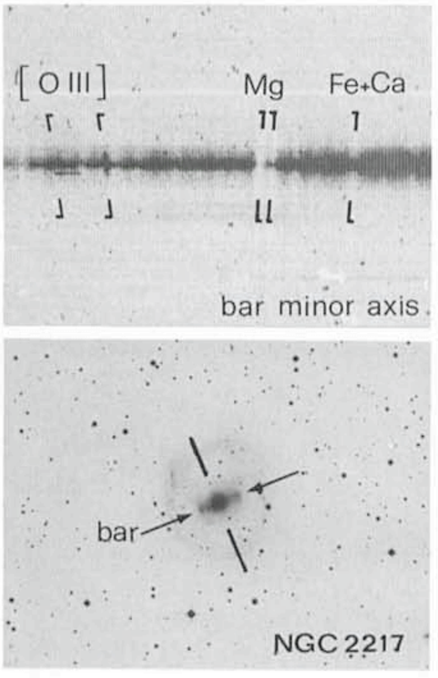

Figure 1: *The almost face-on SB0 NGC 2217 (bottom), and its spectrum along the bar's minor axis (top) showing the opposite tilt of emission and absorption lines. This is the second case of counterrotation between gas and stars found in SB0, after NGC 4546 (Galletta 1986).*

visible for a whole night in the allotted observing period. We selected these galaxies in an effort to have systems with all possible orientations of the bar, from side-on to end-on, and with all possible inclinations of the galaxy disk, from edge-on ($i = 90°$) to face-on ($i = 0°$). Among these, 10 systems have already been observed in the previous runs at La Silla and 7 of these have been fully reduced.

A number (from 4 to 7) of long slit spectra at different P.A. were taken for each galaxy, with exposure times ranging from 60 to 120 minutes, in order to map as much as possible the velocity field. The spectral region observed at the 3.6-m telescope ranged from 3500 to 4500 Å, including Ca II H and K, G-band and the eventually present $\lambda\lambda$ 3727-29 [O II] doublet. The spectral region selected at the 2.2-m ranged from 4800 to 5800 Å, due to the different spectral response of the RCA CCDs adopted, and includes Mg I, Fe and many other bands. When present, Hβ and $\lambda\lambda$ 4959-5007 [O III] doublet were also measured. In addition, the spectrum of some giant stars of low rotational velocity were recorded each night, for use in the reductions as template stars of zero velocity dispersion. All the spectra have been reduced by means of the ESO-IHAP procedures and analysed using the FQ method (Sargent et al., 1977) modified as in Bertola et al. (1984) to produce the stellar velocity and velocity dispersion curves. The emission lines eventually present have been interpolated by fitting gaussian profiles, obtaining the gas velocity curve and the equivalent velocity dispersion σ_{gas} = FWHM/2.53.

The photometric analysis has been performed on frames recorded in band V, I and at wavelengths around Hα on the 1.5-m Danish telescope, with exposure times ranging from 10 to 30 minutes. They have been reduced with the standard ESO-IHAP procedures. The photometric zero point of V band has been obtained using the magnitudes reported by Longo and de Vaucouleurs (1983), while the isophote interpolation has been performed using the INMP programmes (Barbon et al. 1975).

3. Results

The main properties of the SB0 galaxies observed until now are resumed in Table I, where in addition to the galaxies present in our sample we added NGC 936 (Kormendy 1983, 1984) and the four galaxies studied by Jarvis et al. (1988).

We could resume the more interesting findings:

3.1 Velocity fields

Two galaxies were found where gas and stars rotate with similar but opposite streams. This is one of the more remarkable features found, and fully unexpected, which induces some interesting reflections on the nature of the gas in S0 galaxies. Observing NGC 4546, an apparently normal edge-on SB0, we detected the presence in the same spectrum of emission and absorption lines tilted because of the rotation but in opposite way (Galletta 1986, 1987). The amplitude of the observed motions between gas and stars is of the order of 400 km s^{-1} along the apparent major axis. This gas lies in a ~ 5 kpc wide disk not yet relaxed on the main galaxy plane. The second case is represented by NGC 2217, a galaxy with almost round disk isophotes where gas and stars again exhibit opposite motions, circulating around the bar major axis with velocities lower than in the case of NGC 4546, but not negligible (Fig. 1).

In these galaxies the presence of retrograde motions should be interpreted as a recent acquisition from outside, lacking reasonable mechanisms which allow such a clear decoupling between angular momenta of gas and stars having the same origin. They fit in the wider frame of S0s with recent interaction, like the polar ring galaxies (Schweizer et al. 1983) and confirm the idea that the gas in S0 galaxies has an external origin, as suggested for the HI by Wardle and Knapp (1986).

Differences between gas and star kinematics could enhance particular types of orbits. For instance, in the case of NGC 2217 the peculiarities observed could be explained if the gas moved on orbits belonging to the families of anomalous orbits (X-tube, see Van Albada et al. 1982), which appear retrograde when seen from the galaxy pole. This is actually the orientation at which, in an almost face-on galaxy such as NGC 2217, we observe the triaxial ellipsoid represented by its bar. These orbits were originally invoked (Van Albada et al. 1982) to explain the motions observed in the class of elliptical galaxies with minor axis dust lanes (Bertola and Galletta 1978) and represent a typical case where a single family of orbits should be discriminated from the heap of galactic orbits, as discussed in the introduction.

Another family of orbits that should be disentangled from the mass of the others, in the very special case of NGC 4546, is that of the retrograde Z-tube (Contopoulos and Papayannopoulos 1980, Heisler et al. 1982, Teuben and Sanders 1985). These orbits within the bar are elongated parallel to the bar intermediate axis, a direction perpendicular to the most part of the innermost

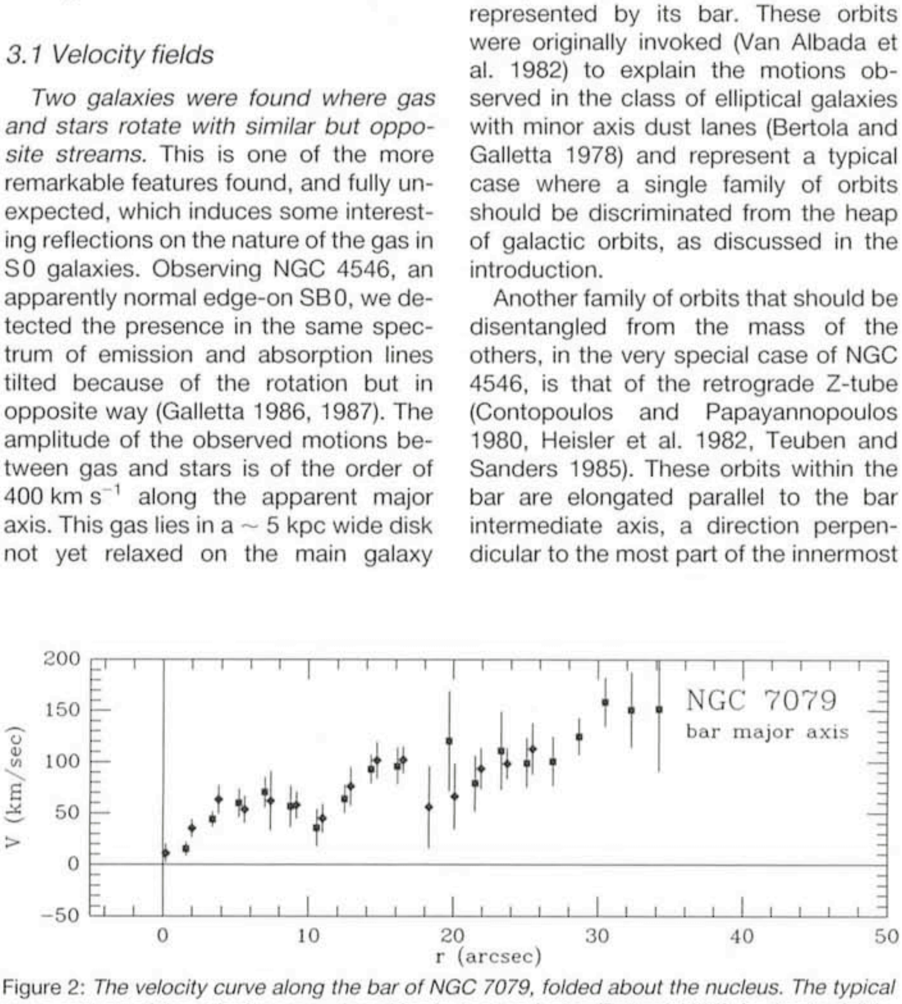

Figure 2: *The velocity curve along the bar of NGC 7079, folded about the nucleus. The typical wavy pattern of the velocity curve, found in six more galaxies (Bettoni 1988), is clearly visible. Different symbols refer to the two opposite sides of the rotation curve.*

Table I: *Properties of the SB0 galaxies studied. The main geometric characteristics of each galaxy, as the estimated inclination* i *with repect to the sky or the presence of ionized gas, are listed. In the following columns are also indicated: the presence of Z-motions (perpendicular to the galactic plane) for almost face-on galaxies; the symmetry of the bar velocity curve with respect to the galaxy nucleus; the presence in it of symmetric oscillations; the trend of the bar velocity dispersion. A question mark indicates data not yet fully reduced.*

Name	GEOMETRY		Ionized gas	BAR KINEMATICS				Ref.	Notes
	Bar-Disk P.A.	i		Presence of Z-motions	Presence of asymmetry	'Double wave' effect	σ_{bar}		
NGC 936	59°	49°	no	–	yes	yes	flat	1	
NGC 1543	–	0°	no	on both axes	no	no	~ flat	5	Double bar
NGC 1574	70°	28°	no	most on min. axis	yes	yes	peaked	5	
NGC 2217	–	24°	faint spiral arms	most on min. axis	?	?	?	7	Gas retrograde
IC 456	79°	48°	yes	–	yes	yes	flat	6	
NGC 2983	51°	47°	no	–	no	yes	peaked	4	
NGC 4371	70°	66°	no	–	?	?	?	7	
NGC 4442	10°	71°	no	–	?	?	?	7	
NGC 4477	58°	24°	no	on both axes	no	yes	flat	5	
NGC 4546	45°	71°	irregular disk	–	no	no	peaked	2	Gas retrograde
NGC 4643	–	0°	no	most on min. axis	yes	no	peaked	7	
NGC 4684	0°	75°	spiral arms, filaments	–	no	no	flat	7	
NGC 4754	60°	59°	no	–	yes	no	flat	5	
NGC 6684	61°	48°	no	–	yes	yes	flat	3	
NGC 7079	43°	43°	yes	–	no	yes	peaked	7	

References: 1: Kormendy (1983), 2: Galletta (1987) 3: Bettoni and Galletta (1988), 4: Bettoni et al. (1988), 5: Jarvis et al. (1988), 6: Bettoni (1988), 7: Bettoni and Galletta, in preparation.

stellar orbits, whose major axes lie on the bar's major axis. Since gas motions in NGC 4546 are retrograde with respect to the stars, the elongation of the isovelocity lines in the two velocity fields (gas and stars) appears at P.A. at almost 90° between them, confirming in this fortunate (and maybe unique) case the existence of this theoretically expected orbits.

Bar kinematics are sometimes asymmetric with respect to the whole galaxy. As generally performed in the reduction of rotation curves, the velocity curve derived from each spectrum was folded about the nucleus and the systemic velocity. In many cases the rotation curves close to the bar differ from the generally symmetric velocity field. In these galaxies, bar motions are actually symmetric, but with respect to a point not coincident with the galaxy nucleus, and independent of the apparent symmetry of the light distribution. This effect should reflect a real misalignment of the bar within the galaxy or the presence of dark and asymmetric matter. It is not yet clear which of these effects could be relevant.

A typical "wave pattern" of the bar rotation curve has been revealed in all the galaxies with intermediate inclination with respect to the sky so far observed. This effect, producing a "double wave" appearance of the unfolded velocity curves, was brought into evidence during the observations of IC 456 (Bettoni 1988) by comparing its bar velocity curve with that already published of the galaxies NGC 936 (Kormendy 1983, Fig. 4b, NGC 6684 (Bettoni and Galletta 1988, Fig. 5) and NGC 2983 (Bettoni et al. 1988, Fig. 4). Similar shapes were detected also in NGC 1574 and NGC 4477 (Jarvis et al. 1988), as well as in NGC 7079. In all these galaxies the velocities rise from the nucleus outward, then reverse their direction reaching minimum (or negative) values and turn back to increase their amplitude, reaching near the end of the bar the values of the general velocity field (Fig. 2). This velocity profile might oscillate around zero (systemic velocity) for galaxies with bar close to the apparent disk minor axis (e.g. NGC 6684) or might be superimposed to the main rotation, if the bar is closer to the major axis (e.g. NGC 936). This trend must not be confused with local minima of the rotation curve which appear outside the

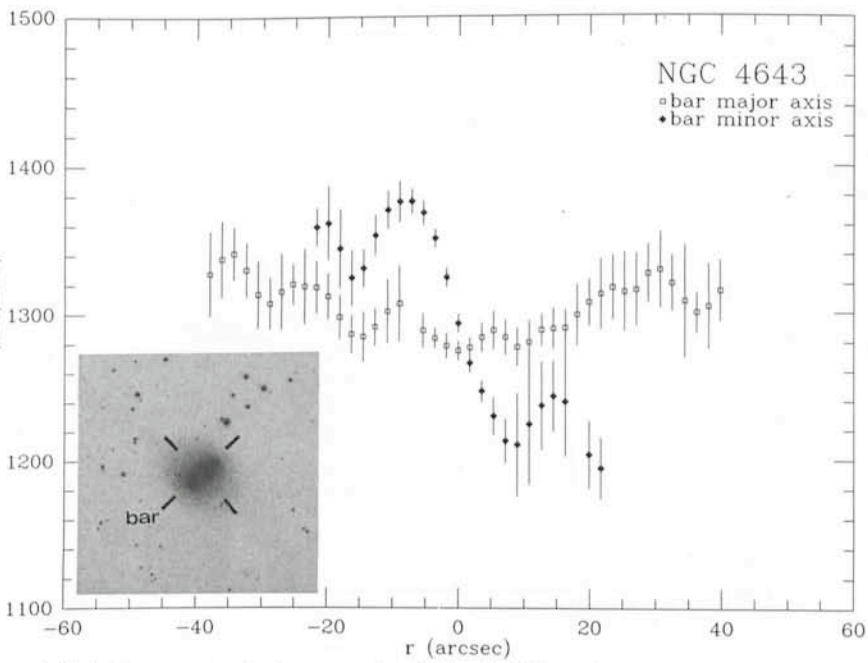

Figure 3: *Velocity curves for the face-on galaxy NGC 4643 (shown in the inset), after a gaussian smoothing of 2". Along the bar, only an asymmetric pattern is visible (open squares) with oscillations of ~ 40 km s⁻¹. On the contrary, the velocity increases as the spectrograph slit is twisted away from the bar going toward the minor axis (full diamonds). At this P.A., symmetric motions with an amplitude of 160 km s⁻¹ are detected. Due to the orientation of the galaxy, these motions should be perpendicular to the galactic plane.*

bar where the bulge fades in the lens or in another component, as is the case of NGC 3945 (Kormendy 1982, Fig. 3) and NGC 2983 itself, where the two phenomena are present (Bettoni et al. 1988, Fig. 4).

On the contrary, no wavy trend around the systemic velocity was detected in NGC 4546 (Galletta 1987), in NGC 1543 and NGC 4754 (Jarvis et al. 1988) or in the two remaining galaxies of the sample so far reduced (see Table I). As an intrinsic feature, the observed wavy trend around the systemic velocity should be due to the presence of retrograde stellar streamings confined to some radii along the bar. A similar feature is expected in many models of barred galaxies which need some amount of retrograde motions. Among these the Freeman (1966a, b) homogeneous bar model, the N-body simulation by Zang and Hohl (1979) and the self-consistent model by Pfenniger (1984a, b). The last study suggests that three-dimensional stellar motions within a barred galaxy should periodically reverse the sense of rotation because of vertical instabilities. In addition, there is the possibility that these motions are produced by a combination of bar and disk streamings in some sectors of the galaxy plane, as suggested by L. Sparke (private communication) on the basis of the analysis of an N-body model of a barred galaxy (Sparke and Sellwood 1987). A more detailed analysis of this property is in progress, but a clear picture will be available only when (and if) the observations of a larger galaxy sample are performed. At this moment we can only say that this effect is observed only in galaxies with inclination between 28° and 53°, lacking in almost face-on or edge-on systems.

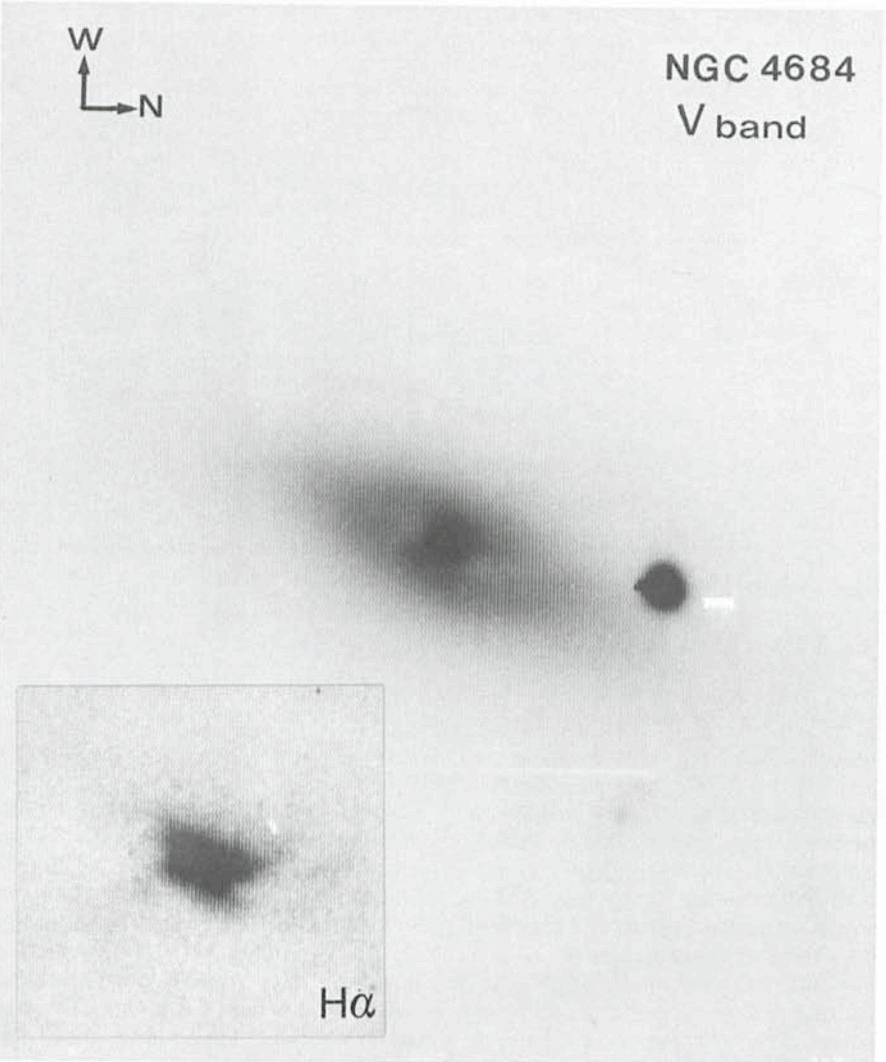

Figure 4: *The inner regions of NGC 4684, in a CCD frame (V band) taken at the 1.5-m Danish telescope. The bar is seen side-on, along the galaxy major axis. In the inset, the nucleus of the galaxy, at the same scale, observed in Hα light. The continuum near Hα has been subtracted. Dust lanes, spiral arms and filaments are visible.*

Stellar and gas streaming perpendicular to the galaxy plane was detected. This is another unexpected point, since it is generally believed that the main part of ordered motions takes place parallel to the main galactic plane. On the contrary, it has been observed in all the 6 almost face-on galaxies considered (see Table I). In the case of NGC 4643, for instance, the velocities along the bar are quite low (~ 40 km s^{-1}), while a wide rotation along the bar minor axis is present, with velocity differences of 160 km s^{-1}) (Fig. 3). A similar condition is present in NGC 1574 (Jarvis et al. 1988) and NGC 2217, while comparable amounts of rotation in both axes were detected in NGC 1543, and NGC 4477 (Jarvis et al. 1988). In some of these cases, this effect should be due to a not fully face-on orientation of the galaxy and/or to the fact that the bar's minor axis is close to the major axis of the disk. Looking at Table I, this could be the case of NGC 1574, NGC 4477 and may be NGC 2217, whose isophotal axial ratio is close to 0.9 (~ 27° of inclination for disks as flat as 0.25). But this hypothesis cannot explain the not negligible velocities found in NGC 1543 and NGC 4643, as well as the amplitude of that observed in the remaining galaxies.

As discussed previously, the gas in NGC 2217 should stream in one of the two possible families of anomalous orbits (see Schwarzschild, 1982), while this hypothesis is less plausible for the stellar motions, distributed in a wider range of energies and not streaming according to a specific orbit. It would be interesting to know if unbarred galaxies also share this property, but until now all requests for observing time on this problem have been rejected. In any case, this feature must be clarified also from the theoretical point of view, having interesting implications on the distribution of the angular momentum in a stellar system since its protogalaxy phase.

Many bars have flat velocity dispersion profiles. In 7 systems over 12 the bar velocity dispersion is characterized by a constant trend, with the peak of the bulge velocity dispersion eventually superimposed. An example of this effect is offered by NGC 6684 (Bettoni and Galletta 1988) or by NGC 4477 (Jarvis et al. 1988). This could indicate that the bars are uniformly hot. A more detailed analysis is necessary to answer this point.

3.2 Photometry and Hα imaging

Many systems have elongated or triaxial components. This agrees with the results of statistical works on rings and bulges (Kormendy 1979, Athanassoula et al. 1982, Buta 1986). A typical collection of these properties is represented by NGC 6684 (Bettoni and Galletta 1988). In this galaxy, the ring is elongated parallel to the bar, in a direction close to that of the line-of-sight. This gives the system the unusual aspect of a galaxy with a ring rounder than the disk. But the bulge also is triaxial. Its isophotes are not aligned at the same P.A. of the disk and the observed stellar motions appear to have a "kinematical line of the nodes" not coincident with the disk major axis, both typical signs of triaxiality. In addition, the bar appears displaced by ~ 2″ from the nucleus of the galaxy along its major axis. Off-centring of the bar (but along the bar's minor axis) is actually observed in some barred galaxies, but generally appears in late spirals, as NGC 4027 (Christiansen and Jefferys 1976, Pence et al. 1988). But with respect to the remaining galaxies of the sample, the offset of the NGC 6684 bar is quite a peculiar feature.

Short and smooth spiral arms, sometimes forming an incomplete ring, appear in some of the studied systems, such as NGC 2983, NGC 4546 and NGC 6684. This feature is brought into evidence by means of a decomposition of the images in the main galaxy components, performed by means of IHAP (see Bettoni et al. 1988). This procedure also indicates that in our sample the bars contain less than 20% of the total light.

The gas in the SB0s observed is concentrated in disks or in complex structures with spiral arms. The Hα imaging of some of the galaxies considered, which possess ionized gas (6 out of 11), indicates a spiral or a not relaxed structure. NGC 2217, for instance, has faint spiral arms in a structure that should be perpendicular to the bar's major axis. This structure recalls the gas in the warped plane which crosses the minor-axis dust-lane galaxies (Bertola and Galletta 1978) and seems to confirm the assumption made previously concerning matter in anomalous orbits. The more extended and complex structures observed in NGC 4546 and NGC 4684 (Fig. 4) represent two more cases of gas whose irregularity strongly suggests a recent acquisition from the outside. Again, as indicated by Wardle and Knapp (1986) for the neutral gas, there are indications of an external origin of most of the gas in S0 galaxies.

This work is dedicated to our daughter Anna, who decided to be born during the drafting of this paper.

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Comet Tempel 2 Turns On

Earlier this year, observers all over the world began to observe Comet Tempel 2, a prime object for the NASA Comet Rendezvous Asteroid Flyby mission (CRAF) in 1993. This short period comet (P = 5.29 years) was first observed in 1873 and has since been seen at no less than 18 apparitions.

This time it was recovered already in December 1986, by Tom Gehrels and his collaborators with the Spacewatch camera. At that time the heliocentric