The dynamical status of Stephan’s Quintet

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ABSTRACT

Multiwavelength data for Stephan’s Quintet (SQ) are consistent with the following model for this compact galaxy group. (1) Discordant redshift NGC 7320 is an unrelated foreground galaxy. (2) In the past SQ was an accordant redshift quartet involving NGC 7317, 18A, 19 and 20C. NGC 7320C collided (probably not for the first time) with the group a few times $10^8$ years ago and stripped the interstellar matter from NGC 7319. (3) In the present SQ is again an accordant quartet involving NGC 7317, 18A,B, and 19. NGC 7318B is now entering the group at high velocity for the first time, giving rise to a shock zone. If most compact groups are like SQ, then they are frequently visited by infalling neighbors that perturb the group and themselves. SQ represents strong evidence for secondary infall in a small group environment. Tidal stripping reduces the mass of the infalling galaxies, thereby increasing the timescale for their orbital decay. There is little evidence that these high velocity “intruders” are rapidly captured and/or merge with the system. Instead they are the mechanism that sustains compact groups against collapse. Efficient gas stripping may account for the low star formation rate observed in compact groups and infall of residual gas into galactic nuclei may also foster the onset of active galactic nucleus activity.

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1. Introduction

Stephan’s Quintet (SQ) epitomizes the problems that compact groups pose for our ideas about galaxy formation and evolution. It is one of the most luminous and high surface brightness aggregates included in the first reasonably complete catalog (Hickson 1982; hereafter HCG) of compact groups (HCG92). Questions center around how many of the galaxies are in close proximity to one another, as well as how long and violently they have been interacting. These questions are particularly relevant because one of the components, NGC 7320, shows a discordant redshift. Finally, there is the question of whether SQ is representative of the compact group phenomenon. It is relevant for the latter question to point out that the accordant redshift part of SQ satisfies the HCG selection criteria - Stephan’s Quartet is also a compact group.

SQ is composed of a kernel of three galaxies (NGC 7317, 18A and 19) with very low velocity dispersion (cz = 6563, 6620 and 6650 km s\(^{-1}\)) respectively; see Moles et al. 1997; hereafter paper I). NGC 7320 (800 km s\(^{-1}\)) and NGC 7318B (5765 km s\(^{-1}\)) complete the apparent compact group. Another accordant redshift galaxy (NGC 7320C, cz\(\sim\)6000 km s\(^{-1}\)) lies 3 arcmin NE of NGC 7319. NGC 7320C is sufficiently faint that its proximity does not violate the HCG isolation criteria. A much brighter spiral galaxy NGC 7331 lies 30 arcmin NE of SQ and shows a redshift (cz = 821 km s\(^{-1}\)) similar to NGC 7320. All seven of these galaxies play a role in our interpretation of the dynamical state of SQ. Figure 1a shows a schematic of SQ and environs, while Figure 2a shows a wide band image of SQ proper. Wide field images can be found in the plates of Arp and Kormendy (1972).

We discuss new optical observations (presented in paper I), as well as published X-ray and radio data. We use them to infer a dynamical history for SQ. Section 2 considers the relationship of discordant-redshift NGC 7320 and the remaining SQ members. We consider the past and present dynamical states of the accordant group in sections 3 and 4 respectively. In section 5 we consider the implications of SQ as representative of the compact group phenomenon.

2. NGC 7320: A Late Type Spiral Projected on an Accordant Quartet

Several investigators have pointed out the low probability for NGC 7320 to be a chance projection on the accordant quartet in SQ (Burbidge and Burbidge 1961; Arp 1973). Little weight would be given to such an \textit{a posteriori} calculation were it not for the fact that discordant components are so numerous in compact groups (\(\sim 43/100\) groups in HCG contain at least one discordant-redshift member; see Sulentic 1994). NGC 7320 shows some peculiarities (see paper I) that could be interpreted as evidence for interaction with the higher redshift SQ members. The most significant involves a blue tidal tail that emerges from the SE end of NGC 7320 (Arp and Kormendy 1972). If we assume that the tidal tail is evidence for recent galaxy-galaxy interaction, we are left with three possible interpretations:

1. it involves only the high redshift members of SQ. In this case NGC 7320 is a foreground galaxy projected on one of the background manifestations of this interaction; or
2. it involves a past encounter between NGC 7320 and NGC 7331. In this case, it is a foreground tail projected near the background high redshift quartet; or
3. it involves direct interaction between NGC 7320 and the accordant SQ. This would require the assumption of non-Doppler redshifts in one (or four) components because the velocity difference between the components is too high for a pure dynamical explanation.

The tail emerging from NGC 7320 is parallel to a second narrower and brighter tail that emerges from one of the the spiral arms in NGC 7319 (see Figure 1b) and extends in the direction of similar redshift NGC 7320C. This fact clearly favors hypothesis 1 because it relates the “NGC7320 tail” to one that is unambiguously related to interaction involving only higher redshift members. The tail emerging from NGC 7320 can actually be traced even farther than the brighter one, and it extends directly to NGC 7320C (Arp and Lorre 1976). Ambiguity in the hypothesis 1 interpretation stems from the fact that NGC 7331 is located in the same direction, but beyond NGC 7320C. Further support for hypothesis 1 comes from a low-redshift H\(\alpha\) image (provided by W. Keel) shown in Figure 2b. The distribution of H\(\alpha\) regions in NGC 7320 is symmetric about its nucleus with no evidence for any low redshift H\(\alpha\) emission in the tidal tail.

Standard redshift-independent distance estimates for NGC 7320 as well as NGC 7317 and 18A,B have
been attempted (paper I; see also Kent 1981; Sulentic 1994). It is unclear whether techniques calibrated with normal galaxies can be reasonably applied to galaxies that are suspected to be, or are manifestly abnormal. The debate over the interpretation of the HI data illustrates this point very well (Sulentic 1994). On the other hand, we show in paper I that some of the galaxies in SQ show only small disturbances (including NGC 7320, if the tail does not belong to it) and, therefore employ normal distance estimators. Indeed, those standard techniques yield distances consistent with the redshift-implied values, i.e., ∼10 Mpc for the low- and ∼65 Mpc for the high-redshift components.

An independent argument for two distances in SQ involves consistency of SQ redshifts with those measured in the surrounding field. Galaxies projected within about one degree of SQ show two preferred redshifts near cz = 800 and 6500 kms\(^{-1}\) (Lynds 1972; Materne and Tamman 1974; Allen and Sullivan 1980 and Shostak et al. 1984). The low redshift galaxies are shaded in Figure 1a to distinguish them from galaxies with redshifts near 6500 kms\(^{-1}\). Two additional galaxies with redshifts similar to NGC 7320 were identified in Shostak et al. (1984) and lie outside the field shown in Figure 1a. The redshift data suggest that the two nearest supercluster structures in the direction of SQ lie at distances of about 10 and 65 Mpc respectively. Rejection of the Doppler interpretation for the high or low redshift parts of SQ would require nearby galaxies to also show discordant redshifts or a fortuitous match of discordant redshifts in SQ with cosmological shifts in the neighboring field.

3. Past History: Encounters with a Nearest Neighbor NGC 7320C

We interpret the kernel of three similar redshift members in SQ as a physical triplet and the core of SQ. These galaxies and NGC 7320C are hatched in Figure 1b. The morphological evidence for physical membership in the triplet is least ambiguous for NGC 7319. NGC 7317 and 7318A show early-type (E2) morphologies and are therefore less sensitive to the effects of gravitational encounters. It is somewhat surprising to find an E-dominated triplet in the field at all, but this morphology might reflect past secular evolutionary effects within the group. However, neither of these ellipticals show an unusual color or signs of geometrical distortion (Schombert et al. 1990; Zepf et al 1991; paper I). The strongest evidence for physical membership of NGC 7317 and 18A comes from the diffuse optical light that surrounds them and that is probably caused by dynamical stripping processes (Arp 1973; Arp and Lorre 1976; Schombert et al. 1990; paper I). NGC 7318B with ∆V ∼850 kms\(^{-1}\) relative to the triplet mean velocity is assumed to be a recent arrival and not relevant for the past dynamical history of SQ (see next section).

The past dynamical history must account for evidence that points to past interactions, especially the following: (1) parallel tidal tails (Arp and Kormendy 1972); (2) stripping of most of the HI from NGC 7319 (Shostak et al. 1984) and (3) diffuse optical light that surrounds the triplet kernel. The first two observations are probably related because an extrapolation backwards of the brighter tail passes very close to the projected center of N7319. The parallel extension of the tails and the fact that both point towards NGC7320C suggest a common origin involving the galaxy. Simulations of galaxy interactions do not usually produce parallel tails (e.g. Howard et al. 1993) leading us to propose that we may be observing the remnants of two past encounters which suggest that NGC 7320C may be a loosely bound member of the system. The tails can reasonably be interpreted as mapping the trajectory of these past encounters if they were caused by NGC 7320C, an hypothesis that we favor here. In the recent past NGC 7320C would have been inside the group and would have formed an accordant (defined as ∆V<10\(^{3}\) kms\(^{-1}\) from group median) quartet with the triplet kernel. That accordant quartet would have satisfied the HCG selection criteria only if NGC 7320 were not superposed. We assume that NGC 7318B had not yet arrived on the scene.

Naturally the spiral member of the SQ kernel (NGC 7319) shows the most dramatic evidence for tidal disruption: 1) the spiral arms are asymmetric, with the eastern arm split into two concentric arcs and the western one ending in one of the tidal tails; 2) the spiral arms show no HII regions on H\alpha images that show them in and near NGC 7318A,B and NGC 7320 (Arp 1973; paper I); 3) NGC 7319 has been stripped of essentially all HI and 4) it shows a Seyfert nucleus and associated radio/optical jet (see paper I and Aoki et al. 1996). Figure 2c shows an H\alpha image (again thanks to W. Keel) centered on NGC7319 that illustrates points 2 and 4. High resolution 21cm observations (Shostak et al. 1984) reveal two extended...
clouds of HI with redshift similar to the stable kernel (see Figure 1b). The total mass of stripped HI with velocity near 6500 km/s is $1.4 \times 10^{10} h^{-1} \, M_{\odot} \, (h = H_0/100)$. This exceed the HI mass of luminous Sb spirals like NGC 7319 by more than a factor of three and implies that some of the stripped gas may have come from other galaxies. The proposed intruder, NGC 7320C, shows a spiral or ringed morphology without evidence for any non-stellar material. The HI velocity listed for NGC 7320C in RC3 catalog is taken from old grid mapping with the Arecibo telescope. Higher resolution and sensitivity observations (Shostak et al. 1984) report no HI at the position of NGC 7320C, therefore some of the stripped HI within SQ may have originated from that galaxy as well. We conclude that most of the damage to NGC 7319 was caused by a direct collision with NGC 7320C (see also Shostak et al. 1984).

The twin tails and diffuse light in SQ show blue colors consistent with recent or ongoing star formation. Grid photometry obtained for SQ by Schombert et al. (1990) find $B-V=0.57$ for the brighter tail which is almost as blue as the foreground Sc spiral NGC 7320. The luminosity of this tail represents about 18% of the luminosity of NGC 7319. The brightest part of the fainter tail was also detected and showed colors in the range 0.1-0.7. Similarly the diffuse light shows colors similar to the disks of spiral galaxies $B-V=0.5-0.7$. The interstellar matter (ISM) in NGC 7319 and possibly other components were stripped and heated to $\sim 10^8$ K (by analogy to the similar ongoing event involving NGC 7318B, see next section). The clouds would then expand, recombine and cool over a time-scale $\sim 5 \times 10^8$ years. Deep images reveal condensations consistent with the size, color and brightness of HII regions (or blue clusters) scattered throughout the halo (e.g. Arp and Lorre 1976). The data supports the hypothesis that much of the stripping occurred in the past few $10^8$ years and also that some tidally induced star formation is occurring or has recently occurred, in the halo and tails.

If the tidal tails map the trajectory of NGC 7320C then it has traveled $\sim 105 \, h^{-1}$ kpc on the plane of the sky since the most recent passage through SQ. NGC 7320C shows an approximate line of sight velocity 700 kms$^{-1}$ lower than NGC 7319 (a ratio of apo-to pericenter of 5-6 assuming NGC 7318A is near the group center of mass). Assuming a transverse velocity equal to the line of sight value suggests that the collision occurred as recently as $1.5 \times 10^8 \, h^{-1}$ years ago. The fainter tail is more diffuse ($2 \times$ broader than the brighter one) which is consistent with the idea that it represents an earlier passage at least $t \geq 5 \times 10^8$ years ago. The roles of NGC 7317 and 7318A in the past dynamical activity or even their past morphologies are impossible to ascertain. An earlier encounter involving NGC 7320C and the southwestern-most tail however would provide a mechanism to account for much of the $\sim 6500 \, \text{kms}^{-1}$ HI and blue halo condensations that are seen west of NGC 7319. The implied trajectory of that tail passes under NGC 7320 and is consistent with a past encounter involving NGC 7318A. We cannot rule out the possibility that NGC 7318A is the remnant bulge of an early spiral whose disk was disrupted in the past (see paper I). In such a view the high early-type galaxy fraction would be a product of dynamical evolution in SQ.

4. Present History: A Penetrating Encounter with NGC 7318B

The present dynamical history of SQ centers on NGC 7318B which shows an $850 \, \text{kms}^{-1}$ radial velocity difference relative to the SQ kernel (these four galaxies are hatched in Figure 1c). This is so large that one might argue that this galaxy is unrelated to the group (an accordant redshift projection) or that it has been dynamically ejected by the triplet kernel. Two observational clues, however, favor the interpretation that NGC 7318B is currently colliding with SQ and for the first time. NGC 7320C is not actively involved in the dynamical evolution of the group at this time.

First, we have reanalyzed the lower velocity HI clouds detected in SQ. Shostak et al. (1984) found four, spatially-distinct HI clouds in SQ with velocities near 5700, 6000 and 6600 (two clouds) kms$^{-1}$. The latter clouds were discussed in the previous section. We interpret the two lower velocity clouds as a single feature. They are adjacent to one another and are centered on the nucleus of NGC 7318B (indicated schematically in Figure 1c or see Figure 4 in Shostak et al. 1984 and paper I). These clouds were previously assumed to be stripped material like the more massive and extensive $\sim 6500 \, \text{kms}^{-1}$ HI clouds. Our reanalysis suggests that they are still associated with the spiral disk of NGC 7318B. That galaxy can plausibly be assigned an Sb or SBb type and therefore would be expected to have a considerable ($\sim 5 \times 10^9 \, M_{\odot}$) HI mass. They show a velocity gradient consistent with
rotation and a central hole coincident with the nuclear bulge region of that galaxy (see Figure 6 in the previous reference). Such holes in the 2D distribution of HI in spiral galaxies with a prominent population II bulge are often seen. The velocity profile of these two clouds taken together show a slightly double-horn structure characteristic of a rotating inclined spiral galaxy. The total HI mass would be approximately $4.1 \times 10^9$ $h^{-1} M_\odot$ with a FWZI velocity gradient of 400 km/s consistent with values for spiral galaxies of similar type and luminosity. The association of this much neutral gas with NGC 7318B suggests that it still retains a significant part of its ISM and, therefore, has not previously passed through SQ.

The second evidence for a direct collision between NGC 7318B and SQ involves VLA radio and recent X-ray data of SQ. ROSAT-HRI mapping (Pietsch et al. 1997) reveals an elongated structure on the east side of NGC 7318B partly coincident with one of its spiral arms. This structure shows a rather close spatial correspondence with a radio continuum arc (van der Hulst and Rots 1981). This structure appears to be sharply bounded and is most easily interpreted as a shock front (it is indicated in Figure 1c and is also well seen in the Hα image shown in Figure 2c). The origin of the shock would most plausibly be ascribed to a high velocity ($\Delta V \approx 10^3$ km/s$^{-1}$) collision between the ISM in NGC 7318B and the stripped gas in SQ. The collision must be ongoing and in its early stages because NGC 7318B retains most of its HI, many HII regions and a reasonably symmetric spiral pattern. Time limits on the duration of this event come from two sources: 1) the lifetime of synchrotron electrons in the radio arc must be a few $\times 10^7$ years without a local source of acceleration (van der Hulst and Rots 1981) and 2) the observed line of sight velocity difference between SQ and NGC 7318B give a similar timescale for the duration of the intruder passage through the group.

In our view, NGC 7318B has replaced NGC 7320C as a high velocity intruder in SQ. The shock is assumed to be associated with the ongoing stripping of NGC 7318B. Optical data also support this view, and the support becomes even more striking when the image of NGC 7318A is subtracted (see paper 1). Most of the complex structure around NGC 7318A and B is consistent with spiral structure associated with the latter high velocity intruder. HII regions can also be seen in the spiral arms as a further indication that this galaxy has not previously sustained a major stripping encounter. The radio/X-ray feature interpreted as a shock front indicates the interface between the unstripped gas disk of NGC 7318B and the ISM in SQ. The narrowness of the shock front suggests that the collision is most easily modeled with NGC 7318B entering the far side of SQ oriented nearly edge-on.

5. The Implications of SQ as a Typical Compact Group

The twin problems posed by compact groups center around the large number of discordant redshift components that they contain, and their gravitational stability. In SQ, at least, the evidence favors the chance projection explanation for discordant NGC 7320. The gravitational stability issue is a problem because attempts at modeling the groups (e.g. Mamon 1986; Barnes 1989) indicate that they should be unstable to collapse on short time scales. In this case the number of compact groups observed today implies that a large merger post-cursor population should exist. Little or no evidence is found for either the mergers in progress (Zepf et al 1991; Moles et al 1994) or for the merger post-cursor population (Sulentic and Rabaça 1994). This has led some to propose that the groups are not real physical systems at all (e.g. Mamon 1986; Hernquist et al. 1995). The large volume of data for SQ can shed some light on these problems, particularly, if our interpretation of its dynamical history is correct and if it is representative of the compact group phenomenon.

Our analysis indicates that SQ is not simply a projection of accordant redshift galaxies. It is a dynamically active system and evidence for this activity is virtual proof that it is a physical aggregate. However the compact group aspect (defined as N ≥ 4 accordant members) is transient in the sense that no fourth tightly bound component can be identified at this time. Instead SQ contains a kernel of three galaxies that must have sufficient mass to attract near neighbors into high velocity encounters. Our best estimate (paper 1) for the combined stellar (galaxy+halo), HI and X-ray gas mass is $M_{SQ} \sim 0.75-1.5 \times 10^{12}$ $h^{-1} M_\odot$. Infall velocities ~800 km s$^{-1}$ were found in n-body simulations of groups with total mass ~$2 \times 10^{13} M_\odot$ (Governato et al. 1996). The infalling galaxies result in dynamical activity that is distinctly episodic. Any catalog of isolated groups will be biased against many of the groups with a currently infalling intruder because the intruder will often “bridge” the group into
its environment and prevent it from satisfying an isolation criterion. NGC7318B is an example of a “safe” (because it is internal) intruder and NGC 7320C is one that almost prevented SQ from satisfying the HCG sample selection criteria.

Is SQ a stable virialized system? This question was first directed towards SQ by Limber and Mathews (1960) before the redshift of NGC 7320 was known. If one repeats this calculation (with \( M/L_B = 13h \) for NGC 7317, 18A and 20C as well as \( M/L_B = 8h \) for NGC 7318B and 19) it suggests that the triplet kernel is stable with \( 2T/\Omega \sim 0.8 \) but that inclusion of NGC 7318B and 20C yields \( 2T/\Omega \sim 11 \). NGC7320C forms a marginally stable quartet with the triplet kernel with \( 2T/\Omega \sim 2 \). These estimates do not take into account the large amount of (baryonic) mass present in the halo or the possible role of non-baryonic matter that might be needed to produce the observed infall velocities. The virial calculation and optical images (the twin tidal tails) interpreted as evidence for recent passage(s) through the group suggests that NGC 7320C has been recently captured by the kernel. Finally, NGC 7318B is almost certainly entering the group for the first time. Thus, SQ is probably a bound triplet that has captured a fourth member (NGC 7320C) within the past Gyr and is now being visited by another (NGC 7318B).

Governato et al. (1996) have advanced one of the most complete scenarios for the formation and evolution of compact groups. They create groups in a critical universe by 1) seeding them with primordial merger events and 2) growing present day groups with secondary infall onto these seeds. Our study of SQ strongly supports the second part of this model including the conclusion that the infall will be high velocity and will resist rapid merging. It also supports the qualitative discussion of Moore et al. (1996) that sees high velocity intruders as an effective means to dynamically evolve galaxies and create diffuse halos. They consider random high velocity encounters in clusters while compact groups are found in non-cluster environments (Sulentic 1987). While high relative velocities in clusters are due to the high internal velocity dispersion, the lower mass of small groups such as SQ implies that only infalling galaxies can achieve velocities \( V > 500 \text{ km s}^{-1} \).

In our case the seed is not a single merger remnant as proposed by Governato et al. (1996) but a triplet. The over-representation of luminous elliptical galaxies in the triplet suggests that it may also have experienced strong dynamical evolution as it formed perhaps by a random initial encounter between three spirals(?) . It is not clear if dynamical evolutionary effects have significantly altered the properties of NGC 7317 or NGC 7318A because their morphologies, colors and kinematics appear rather normal. Thus they could be ellipticals or remnant spiral bulges. Existing images do not allow a distinction between these possibilities. An extrapolation of the tail under NGC 7320 is consistent with an encounter trajectory where NGC 7320C would have passed very near NGC 7318A as recently as \( \sim 1 \text{ Gyr} \) ago. There is sufficient stripped gas to account for three or four spiral galaxies. The presence of radio continuum and X-ray emission in the nuclear regions of NGC 7318A may indicate an active past history.

A luminous halo surrounds the triplet which indicates that it is a dynamically evolved physical system. Our conservative estimate of the halo luminosity (V band: see paper 1) gives \( M_{\text{halo}} = -20.9 + 5\log(h) \geq M_\ast \). This is almost ten times the luminosity of the tail created in the most recent passage of NGC7320C. Neither tail was included in this estimate but each will increase the halo luminosity by \( \sim 10\% \). It is the high velocity intruders that cause SQ to grow (in galaxy population and halo mass) and that prevents the triplet kernel from coalescing by injecting kinetic energy into the group. In this view SQ must be a relatively young group unless NGC7320C has been perturbing it for a longer time; otherwise the triplet should have merged. This would require the triplet to form and dynamically evolve in the past 1-2 Gyr. Assuming that the halo was created by similar processes (a tidal tail at a time) and at about the same rate (one \( M_V = -18.4 + 5\log(h) \text{ tail per } 5 \times 10^8 \text{ years} \)), would imply an age of several Gyr for its formation. SQ may not be primordial but the stable-kernel part of it is at least 2 Gyr old.

Neither of the elliptical components in the kernel show luminosities or other properties consistent with having been recent mergers. In this respect SQ is typical of other compact groups where no evidence for ongoing merging is seen (Zepf and Whitmore 1991; Moles et al. 1994). If our view is correct, then rather than mergers, these ellipticals may be the dynamically evolved remnants of spiral galaxies. SQ is also similar to other compact groups in the sense that its optical and FIR emission properties indicate a lower level of current star formation activity than is observed in pairs (Sulentic and de Mello Rabaça 1994;
Moles et al. 1994). SQ suggests that the lack of starburst activity in compact groups is due to the lack of bound gaseous disks in many component galaxies. In SQ a major stripping event happened in the recent past and another is in progress. The gas is either stripped and neutral or shocked and hot. A large intergroup star forming region is observed in Hα emission within the group but outside of the galaxies (see Figure 2c). However so much of the gas in SQ is stripped or shocked that it is too diffuse (cool or hot) to form large numbers of stars. The FIR emission from SQ is not strong especially when allowances are made for possible contributions from NGC7320 and the Seyfert nucleus in NGC7319. The excess FIR emission expected from these sources apparently cannot compensate for the deficit emission from SQ component galaxies. The transition from a normal star forming disk to the shocked state should be quite sudden given the high velocity of this intruder. Given the efficiency and quasi-periodic nature of the tidal perturbation in compact group, it is tempting to ascribe the Seyfert activity in NGC7319 to the past intruders as well. Whatever gas was not stripped may have been rapidly channeled into the nucleus to fuel active galactic nucleus (AGN) activity.

SQ suggests that compact groups consist of a tightly bound subsystem (kernel or seed) plus a loosely bound, or even unbound, population of infalling neighbors. The most common situation for HCG groups would involve a triplet or quartet acting as a seed plus 1 or two intruders. Indeed, it is easier to form a bound pair than a triplet, but given the n≥4 number criterion used in HCG, triplets would be more often selected because it is easier to have a 3+1 rather than 2+2 configuration. The kind of dynamical encounters do not lead to rapid merging suggested by many models. The intruders are stripped which reduces their mass and cross section to frictional effects. At the same time they inject energy into the kernel which sustains it against collapse. Some stars form but not as many as commonly observed in more dynamically stable pairs. The more frequent and high impulse events in compact groups may also foster AGN activity at a higher rate than pairs do. It is perhaps appropriate that the first compact group discovered more than a century ago provides the clearest clues to their origin and evolution.

REFERENCES

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Fig. 1.— (a) Schematic of the Stephan’s Quintet area. Low redshift galaxies ($V_0 \sim 800 \text{kms}^{-1}$) are shaded. All other indicated galaxies have redshifts near $\sim 6000 \text{kms}^{-1}$. Galaxies discussed in the text are labeled. The dotted region indicates the area shown in Figure 1b. (b) Map of the immediate environment of SQ. Galaxies involved in the past dynamical history are shaded. The two optical tails are indicated along with the rough extent of HI clouds near 6500 kms$^{-1}$. (c) Similar map to Figure 1b but shifted to the west by $\sim 30$ arcsec. Galaxies involved in the present dynamical history are shaded. The region of the radio synchrotron and X-ray shock feature is indicated along with the approximate extent of HI clouds near 5700 and 6000 kms$^{-1}$.

Fig. 2.— (a) R band image of SQ obtained with the 1.5m telescope at Calar Alto (Spain). The large and small boxes indicate the field of view for the low and high redshift H$\alpha$ images shown in 2b and 2c respectively. (b) Continuum subtracted low-redshift H$\alpha$ image for NGC 7320 and projected tidal tail. Images were obtained with a 1m telescope at Lowell Observatory using a $398 \times 398$ pixel CCD (0.706 arcsec/pixel). H$\alpha$ image was the average of four 20 min. exposures through a filter with effective width of 70$\text{Å}$ centered at 6600$\text{Å}$. Continuum frame was a single 10 min. R exposure. (c) Continuum subtracted high-redshift H$\alpha$ image for NGC 7318b and 19 and the region of the shock front. Images were obtained with the 2.1m telescope at KPNO using a $796 \times 796$ pixel CCD (0.194 arcsec/pixel). The H$\alpha$ filter had a peak wavelength at 6693$\text{Å}$ with FWHM of about 65$\text{Å}$. It was a single 20 minute exposure. There was a matching 10 minute R band continuum exposure. We thank Bill Keel for kindly providing access to these unpublished images.