Interpretation of the Stephan Quintet Galaxy Cluster using
Hydro-Gravitational Theory

Carl H. Gibson¹
Departments of Mechanical and Aerospace Engineering and Scripps Institution of
Oceanography, University of California, San Diego, CA 92093-0411
cgibson@ucsd.edu

and

Rudolph E. Schild
Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138
rschild@cfa.harvard.edu

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¹Center for Astrophysics and Space Sciences, UCSD
ABSTRACT

Stephan’s Quintet (SQ) is a compact group of galaxies that has been well studied since its discovery in 1877 but has not been understood using cold dark matter (CDM) cosmology. Anomalous red shifts $z = (0.0027, 0.019, 0.022, 0.022, 0.022)$ among galaxies in SQ either reduce it to a Trio with two intruders or support the hypothesis that red shifts may be intrinsic. An alternative to the CDM and intrinsic red shift interpretations is provided by the Gibson 1996-2000 hydrogravitational-theory (HGT) where superclusters, clusters and galaxies originate in the super-viscous plasma epoch by fragmentation. By this interpretation, the SQ cluster galaxies separated only recently and remain along a line of sight because of perspective and small transverse velocities from their sticky viscousgravitational beginnings. According to HGT, observed star and gas bridges and young-globular-star-cluster (YGC) trails are triggered as SQ members separate through each other’s frozen baryonic-dark-matter halos of dark proto-globular-cluster (PGC) clumps of planetary-mass primordial-fog-particles (PFPs).

Subject headings: cosmology: theory, observations — dark matter — Galaxy: halo — gravitational lensing — turbulence

1. Introduction

Stephan’s Quintet (SQ, HGC 92, Arp 319, VV 288) is one of the first known (Stephan 1877) and best studied of the Hickson 1982 catalog of very compact groups of galaxies, and historically the most mysterious. The group consists of the Trio NGC 7319, NGC 7318A, and NGC 7317, all of which have redshift 0.022, NGC 7318B with redshift 0.019 closely aligned with NGC 7318A, and NGC 7320. Burbidge and Burbidge 1959 noted that the
large discrepancy of redshifts for the double galaxy NGC 7318AB requires huge mass/light $(M/L)$ ratios $\approx 300 \pm 200$ from dynamical models to achieve virial equilibrium. However, the true mystery of SQ began when the missing redshift for NGC 7320 was determined by Burbidge and Burbidge 1961 to be only $z = 0.0027$, with relative velocity $cz = 8.1 \times 10^5$ m/s compared to $6.7 \times 10^6$ for the Trio. For virial equilibrium, this increases the kinetic energy of the group by a factor $\sim 30$ and would require $M/L \approx 10,000$: much too large to be credible. Thus it was concluded (Burbidge and Burbidge 1961) that the system is in a state of explosive expansion since the a priori chance of NGC 7320 not being a member of the group but a random foreground galaxy is about $1/1500$.

Another possibility is that the SQ redshifts are variable because the galaxies were ejected from a nearby parent AGN since from other observations galaxies and quasars frequently show evidence of ejection with intrinsic redshifts (Hoyle et al. 2000). Arp 1973 summarizes several papers from 1970-1972 where he concludes that the nearby large spiral galaxy NGC 7331 has ejected all the SQ galaxies, some with intrinsic redshifts, so that all the SQ galaxies are located at the same $\approx 10$ Mpc distance of their parent NGC 7331. Arp has noted numerous cases where galaxies in close angular proximity have not only widely different redshifts but coincident spin magnitudes and alignments with AGN jets consistent with his hypothesis that galaxies and quasars can be ejected from active galactic nuclei (AGNs) with intrinsic redshifts (Arp 1998). It has been suggested (Hoyle et al. 2000) that the big bang hypothesis itself should be questioned based on an accumulation of such coincidences contrary to statistics of standard CDM hierarchical galaxy clustering cosmology and the red-shift radial-velocity relationship ($v = cz$) of big bang cosmology.

The contradictions and mysteries that arise from the SQ observations interpreted using standard cold-dark-matter (CDM) cosmology vanish if the observations are interpreted using the hydro-gravitational-theory (HGT) of Gibson 1996-2000. Similar red shift mysteries for
other compact groups and aligned galaxies and quasars also vanish. From HGT cosmology the alignment of locations, spins and the close angular proximity of galaxies with different red shifts are interpreted as fossils of the viscous-gravitational beginnings of galaxy clusters and galaxies, where their apparent spatial proximity is an optical illusion resulting from the small transverse velocities of the galaxies (due to early friction as they gently fragmented from the same cluster) so they can have wide separation precisely along a line of sight from the extremely uniform expansion of space in the universe at these scales expected from big bang cosmology.

Moles et al. 1997 summarize the data and dynamical status of SQ consistent with standard CDM cosmology, proposing that the nearby NGC 7320C with \(cz = 6.0 \times 10^5\) m/s (matching that of NGC 7318B) has possibly collided several times with SQ members stripping their gas and central stars to form luminous wakes and to preserve their dynamical equilibrium, thus accounting for the fact that 43 of the 100 members of the Hickson 1982 catalog of compact groups contain discordant redshift members. However, Gallagher et al. 2001 show from their Hubble Space Telescope (HST) measurements that globular star clusters in SQ are not concentrated in the inner regions of the galaxies as observed in numerous merger remnants, but are spread over the SQ debris and surrounding area. We see no evidence of collisions or mergers in the HST images of SQ and suggest the luminous wakes are not gas stripped from galaxy cores by collisions but are new stars triggered into formation in the baryonic-dark-matter halo of the SQ cluster as member galaxies are gently stretched away by the expansion of space.

According to HGT, galaxy mergers and collisions do not strip gas but produce gas by evaporating the frozen hydrogen and helium of the planetary mass objects which dominate the baryonic mass of galaxies. The baryonic dark matter is comprised of proto-globular-star-cluster (PGC) clumps of planetary-mass primordial-fog-particles (PFPs)
from hydro-gravitational-theory (Gibson 1996) and quasar microlensing observations (Schild 1996). From HGT the cores of SQ galaxies are deficient in gas and YGCs because they have not had mergers or collisions.

According to standard CDM cosmology, galaxies and clusters of galaxies are all formed by hierarchical collisionless clustering due to gravity, as suggested by N-body computer models, starting with small primordial CDM seeds from the plasma epoch after the big bang where the Jeans 1902 gravitational condensation criterion rules out any condensation of the ordinary baryonic matter. However, CDM seeds are hydrodynamically impossible from HGT, and their clustering to form galaxies is ruled out by observations (Sand et al. 2002). According to HGT the Jeans 1902 criterion and the standard CDM cosmology based on this criterion are fundamentally incorrect and misleading. The unknown non-baryonic CDM material is enormously diffusive compared to the H and He ions of the primordial plasma and cannot condense or fragment gravitationally. Structure formation first occurs according to HGT when viscous or weak turbulence forces of the primordial plasma match gravitational forces at scales smaller than the horizon scale $ct$, where $c$ is the speed of light and $t$ is the time after the big bang. This occurs at $t \approx 10^{12}$ s (Gibson 1996). The HGT-cosmology and its application to the interpretation of SQ is illustrated schematically in Figure 1ab.

In Fig. 1a at top left we see a proto-supercluster ($10^{47}$ kg) fragment of the primordial plasma as it separates from other such fragments due to the rapid expansion of the universe at the time of first gravitational structure formation about 30,000 years after the big bang (Gibson 1996). The scale is near the horizon scale $ct$ at that time $3 \times 10^{20}$ m with baryonic density $2 \times 10^{-17}$ kg/m$^3$ and non-baryonic density $\approx 10^{-15}$ kg/m$^3$ decreasing with time as the universe expands and the non-baryonic matter (probably neutrinos) diffuses to fill the voids and reduce the gravitational forces (Gibson 2000). In Fig. 1a center proto-cluster
a. According to hydro-gravitational cosmology (Gibson 1996), proto-superclusters (left) fragment to proto-clusters (center) which fragment to form proto-galaxies during the super-viscous plasma epoch. Compact galaxy clusters such as Stephan’s Quintet occur in this cosmology when dispersal of the cluster by the expansion of the universe is delayed by frictional forces; e.g., the central cluster of galaxies on the right. 
b. Galaxies of the fragmented SQ cluster remain along a line of sight to the SQ Trio because of their small transverse velocities, reflecting their sticky beginnings. The $2 \times 10^{21}$ m (60 kpc) diameter SQ thin tube begins with NGC 7320 at a distance of $2.7 \times 10^{23}$ m (9 Mpc) and ends with the SQ Trio at $2.2 \times 10^{24}$ m (74 Mpc). NGC 7318B is 10 Mpc closer than the Trio.
fragments form and separate as the universe expands, and on the right proto-galaxies fragment just before the cooling plasma turns to gas at 300,000 years ($10^{13}$ s). The proto-galaxies preserve the density and spin of the proto-supercluster as fossils of the primordial plasma turbulence (Gibson 1999). Their initial size is therefore about $5 \times 10^{19}$ m. These fragment into ($10^{36}$ kg) proto-globular-cluster (PGC) dense clouds of ($10^{24}$ kg) primordial-fog-particles (PFPs) that cool, freeze, and diffuse away from the galaxy cores to form baryonic-dark-matter (BDM) halos around galaxies and galaxy-clusters such as SQ. Some galaxy-clusters can be very slow in their separation due to crowding and frictional forces of their BDM halos, as shown by the central galaxy cluster at the right of Fig. 1a. The BDM halo may reveal the history of galaxy mergers and separations because strong tidal forces and radiation by galaxy cores trigger the formation of stars and YGCs as they and their halos move through each other’s BDM halos, leaving star wakes and dust wakes.

Fig. 1b shows schematically our interpretation of SQ based on HGT. The five galaxies are separated by distances inferred from Hubble’s law and their red shifts times the horizon distance $10^{26}$ m due to the stretching of space along a thin square tube of diameter $\approx 2 \times 10^{21}$ m oriented along the line of sight to the Trio. The distance to the line-of-sight tube entrance from earth is thus $\approx 2.7 \times 10^{23}$ m for NGC 7320, with the exit and Trio at $\approx 2.2 \times 10^{24}$ m. NGC 7320 appears larger than the Trio members because it is closer, consistent with the fact that it contains numerous obvious young-globular-clusters (YGCs) from the HST images, but YGCs in the Trio are barely resolved (Gallagher et al. 2001). The tube in Fig. 1b is not to scale. The actual aspect ratio is that of a meter long stick of uncooked spaghetti. By perspective, 1.5% of the front face of the tube covers the back face.

Figure 2 shows an HST image of Stephan’s Quintet. The trail of luminous material extending southeast of NGC 7319 is interpreted from HGT as a star wake formed as one of the galaxy fragments of the original cluster moves away from the clump of galaxies.
through the baryonic-dark-matter (BDM) halo, triggering star formation until it exits at the halo boundary marked by a dashed line. Other star wakes in Fig. 2 are also marked by arrows. These star wakes are similar in origin to the filamentary galaxy VV29B of the Tadpole merger (Gibson & Schild 2003) and the ”tidal tails” of the Mice and Antennae merging galaxies, except that in SQ all the galaxies separated rather than merged through each other’s halos, contrary to the standard SQ (Moles et al. 1997) model. Two dust trails are shown by arrows in the upper right of Fig. 2 that we interpret as star wakes of the separation of NGC 7318B from NGC 7318A. A similar dust trail is interpreted from its direction as a star wake of NGC 7331 produced in the NGC 7319 BDM halo as it moved out of the cluster. The luminous trail pointing toward NGC 7320C is confirmed by observed gas patterns (Gutierrez et al. 2002) from broadband R measurements that suggest NGC 7320 has the same origin near NGC 7319. It is not clear what galaxy or galaxies separated in the northern star forming region, leaving over a hundred YGCs (Gallagher et al. 2001) before exiting the BDM halo boundary shown by the dashed line in the upper left of Fig. 2.

Details of the Hubble Space Telescope images of Stephan’s Quintet (including Fig. 2) can be found at the website for the July 19, 2001 STScI-2001-22 press release (http://hubblesite.org/newscenter/archive/2001/22/image/a). The images are described as “Star Clusters Born in the Wreckage of Cosmic Collisions” reflecting the large number of YGCs detected (Gallagher et al. 2001) and the standard SQ model (Moles et al. 1997). According to our HGT interpretation, none of the YGCs are due to galaxy collisions or mergers. All are formed in the BDM halos as the galaxies gently separate with small transverse velocity along lines of sight. There were no cosmic collisions or wreckage. Numerous very well resolved YGCs can be seen in the NGC 7320 high resolution image with separations indicating numbers in the range $10^5$ – $10^6$. This suggests a significant fraction the dark baryonic matter in the halo of NGC 7320 has been triggered to form YGCs and stars as the galaxy separated through both the dense BDM halo of the SQ Trio and the
Fig. 2.— Hubble Space Telescope image of Stephan’s Quintet. Dust and star wakes (arrows) are produced as SQ related galaxies separate from each other through the cluster baryonic-dark-matter (BDM) halo of PGCs and PFPs triggering star formation.
BDM halo of its companion galaxy NGC 7331, also at $z = 0.0027$. No such concentration of YGCs can be seen in the SQ Trio galaxies, consistent with our HGT interpretation that they are at 8.3 times the distance of NGC 7320 as shown in Fig. 1b.

2. Stephan’s Quintet Observations

The present status of observations of Stephan’s Quintet is well summarized by Gutierrez et al. 2002, including their deep broadband R and narrowband $H\alpha$ maps shown in Figure 3. The R band map (their Fig. 1) with sensitivity 26 mag arcsec$^{-2}$ extends to a wide range that includes NGC 7320C with the other SQ member galaxies. A clear $H\alpha$ bridge is shown with red shift $z = 0.022$ corresponding to that of the SQ Trio to a sharp interface with $z = 0.0027$ material in NGC 7320, consistent with our interpretation that the bridge was formed in the BDM halo of the SQ Trio by NGC 7320 as it emerged and separated by the expansion of the universe along the line of sight, as shown by the dashed arrow in Fig. 2.

A corresponding dashed arrow in Fig. 3 shows the new $H\alpha$ bridge from the SQ Trio at red shift 0.022 with sharp transition to 0.0027 at NGC 7320, proving the two are widely separated in space but likely with the same origin, as we show is expected from HGT in Fig. 1b.

The solid arrow shown in Fig. 3 toward NGC 7320C suggests its emergence from the SQ Trio BDM halo leaving the star wake shown by a corresponding arrow in Fig. 2. The mechanism of star wake production is that the frozen PFPs are in meta-stable equilibrium within their PGCs. Radiation from a passing galaxy causes evaporation of gas and tidal forces which together increase the rate of accretion of the PFPs to form larger planets and finally stars. The size of the stars and their lifetimes depends on the
Fig. 3.— Contour R map of SQ (Gutierrez et al. 2002) showing connections between SQ galaxies and NGC 7320C to the East (left), and NGC 7320 to the South (bottom). The $H_{\alpha}$ bridge is at the red shift 0.022 of the SQ Trio, and shows a sharp transition to $z = 0.0027$ for NGC 7320 (Gutierrez et al. 2002), consistent with our HGT interpretation that SQ galaxies have been stretched along a thin pencil by the expansion of the universe, see Fig. 1b.
turbulence levels produced in the gas according to HGT. Large turbulence levels produce large, short lived stars. The dust lane between NGC 7318A and its double NGC 7318B suggests large turbulence levels produced large stars that have since turned to dust through supernovas. A similar dust lane from NGC 7219 is in the general direction of NGC 7331 and its companions, as indicated by the arrow in Fig. 2.

3. Conclusions

We conclude that Stephan’s Quintet is well described by hydro-gravitational-theory and cosmology (Gibson 1996). According to HGT cosmology, all the SQ galaxies formed by fragmentation of the primordial plasma just before photon decoupling and transition to gas 300,000 years after the big bang, and none show evidence of subsequent collisions or mergers. They remained stuck together for 12.9 billion years until 220 million years ago when the final few galaxies of the original supercluster finally overcame the gravitational binding forces and the frictional forces of the cluster baryonic-dark-matter halo and began their separation due to the expansion of the universe.

The nature of the baryonic-dark-matter halo is explained by HGT and supported by the SQ observations. At the plasma-gas transition the proto-galaxy plasma clouds turned to gas. From HGT (Gibson 1996) the gas fragmented at both the Jeans scale, to form proto-globular-star-cluster (PGC) clumps \(10^{36}\) kg, and the viscous Schwarz scale, to form small-planetary-mass \(10^{24}\) kg primordial-fog-particles (PFPs), consistent with the conclusion (Schild 1996) from quasar microlensing observations that the lens galaxy mass is dominated by “rogue planets likely to be the missing mass”.

Some of the PFPs near the proto-galaxy centers accreted to form stars and the luminous galaxy cores. Most PFPs condensed and froze as the universe expanded and
cooled so their PGCs remained dark and gradually diffused away from the galaxy cores to form BDM galaxy halos, and some diffused further to form cluster baryonic-dark-matter (BDM) halos. The Stephan Quintet cluster BDM halo boundaries are revealed by the separation of the SQ galaxies as star wakes, as shown in Fig. 2. The SQ BDM halo radius is only \( \approx 2 \times 10^{21} \) m, compared with the galaxy BDM halo radius of the Tadpole galaxy \( \approx 5 \times 10^{21} \) m as shown by HST/ACS images of the star wake of the merging galaxy (Gibson & Schild 2003).

Our HGT interpretation of SQ solves the long standing mystery of its anomalous red shifts (Burbidge and Burbidge 1961). Rather than an explosive expansion or intrinsic red shifts of the SQ galaxies ejected by the same parent (Arp 1973) we suggest that a uniform expansion of the universe could stretch the SQ galaxies along a line of sight as shown in Fig. 1b because of small transverse velocities from their sticky beginnings predicted by HGT. Their common point of origin is confirmed by recent R and \( H_\alpha \) observations (Gutierrez et al. 2002).
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