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

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Stephan’s Quintet (SQ) is a compact group of galaxies that has been well studied since its discovery in 1877 but is mysterious using cold dark matter hierarchical clustering cosmology (CDMHCC). 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 highly improbable intruders from CDMHCC, or support the Arp (1973) hypothesis that its red shifts may be intrinsic. An alternative is provided by the Gibson 1996-2000 hydro-gravitational-theory (HGT) where superclusters, clusters and galaxies all originate by universe expansion and gravitational fragmentation in the super-viscous plasma epoch (after which the gas condenses as $10^{24}$ kg fog-particles in metastable $10^{36}$ kg dark-matter-clumps). By this fluid mechanical cosmology, the SQ galaxies gently separated recently and remain precisely along a line of sight because of perspective and the small transverse velocities permitted by their sticky, viscous-gravitational, beginnings. Star and gas bridges and young-globular-star-cluster (YGC) trails observed by the HST are triggered as SQ galaxies separate through each other’s frozen baryonic-dark-matter halos of dark proto-globular-cluster (PGC) clumps of planetary-mass primordial-fog-particles (PFPs). Discordant red shifts (from CDMHCC) between angularly clustered quasars and bright galaxies are similarly explained by HGT.

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 red shifts are intrinsically variable because the SQ galaxies were all recently ejected from a nearby parent AGN. 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 and some have intrinsic red shifts, 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 red shifts but coincident spin magnitudes and alignments with the AGN jets, consistent with his hypothesis that galaxies and quasars can be ejected from active galactic nuclei (AGNs) with intrinsic red shifts (Arp 1998).

Galaxies and quasars frequently show evidence of ejection with intrinsic red shifts
(Hoyle et al. 2000). A Seyfert 1 galaxy (NGC 6212) is observed closely surrounded by a large number (≥44) of QSOs that it may have ejected (Burbidge 2003), with QSO surface densities (69 per square degree) larger than ambient by estimated factors of 30 to 10 and decreasing (to 17) with angular distance for radii 10–50 minutes. It has been suggested (Hoyle et al. 2000) that the big bang hypothesis itself may be questioned based on the remarkable accumulation of such coincidences that are contrary to the statistics of standard CDM hierarchical galaxy clustering cosmology (CDMHCC) and the Hubble red-shift radial-velocity relationship (v = cz) of big bang cosmology.

The contradictions and mysteries vanish concerning SQ anomalous red-shifts and large QSO densities near AGNs when the observations are interpreted using the hydro-gravitational-theory (HGT) of Gibson 1996-2000. From HGT cosmology such improbable coincidences (from CDMHCC) are simply fossil manifestations of the viscous-gravitational beginnings of galaxy clusters and galaxies, where the apparent close proximity is an optical illusion resulting from the small transverse velocities of the galaxies due to early friction as they gently fragmented gravitationally from the same proto-supercluster. Thus, dense angular galaxy clusters can have wide spatial separations precisely along a line of sight from the uniform expansion of space expected from big bang cosmology. From the large range of redshifts (0.03 to 2.6) and Hubble distances (150 to 3730 Mpc) of the NGC 6212-quasar system (Burbidge 2003) the observed AGN-QSO galaxies are concentrated in a thin (≈150/1) line-of-sight pencil, contradicting CDMHCC and supporting HGT. HGT has recently been reviewed and compared to data (Gibson & Schild 2003), so in the following we present only a brief summary.
2. Hydro-Gravitational Theory

Standard CDMHC cosmologies are based on over-simplified fluid mechanical equations, an inappropriate assumption that the fluid is collisionless, and a recognized “swindle” required to achieve solution of the equations. The Jeans 1902 theory neglects viscous forces, turbulence forces, non-acoustic density fluctuations, particle collisions, and the effects of diffusion on gravitational structure formation. Jeans did linear perturbation stability analysis (neglecting turbulence) of Euler’s equations (neglecting viscous forces) for a nearly uniform ideal gas with density $\rho$ only a function of pressure (the barotropic assumption), which reduced the problem of gravitational instability to the solvable equation of gravitational acoustics. To reconcile his equations with the linearized collisionless Boltzmann’s equations and the resulting Poisson’s equation for the gravitational potential, Jeans assumed the density $\rho$ was zero. This assumption is appropriately known as the “Jeans swindle”. The only critical wave length for gravitational stability with all these questionable assumptions is the Jeans length scale $L_J$ where

$$L_J \equiv V_S/(\rho G)^{1/2} \approx (p/\rho^2 G)^{1/2},$$

(1)

$G$ is Newton’s gravitational constant and $V_S \approx (p/\rho)^{1/2}$ is the sound speed.

Density fluctuations in fluids are not barotropic as assumed by Jeans 1902 except rarely in small regions for short times near powerful sound sources. Density fluctuations that triggered the first gravitational structures in the primordial fluids of interest were likely non-acoustic (non-barotropic) density variations from turbulent mixing of temperature or chemical species concentrations produced by the big bang (Gibson 2001) as shown by turbulent signatures in the cosmic microwave background temperature anisotropies (Bershadskii and Sreenivasan 2002). From Jeans’ theory without Jeans’ swindle, a gravitational condensation on an acoustical density maximum rapidly becomes a non-acoustical density maximum because the gravitationally accreted mass retains the
(zero) momentum of the motionless ambient gas.

Without viscous and turbulent forces or diffusion, fluids with non-acoustic density fluctuations are absolutely unstable to the formation of structure due to self gravity (Gibson 1996). Turbulence or viscous forces can dominate gravitational forces at small distances from a point of maximum or minimum density to prevent gravitational structure formation, but gravitational forces will dominate turbulent or viscous forces at larger distances to cause structures if the gas or plasma does not diffuse away faster than it can condense or rarify due to gravity. The concepts of pressure support and thermal support are artifacts of the erroneous Jeans criterion for gravitational instability. Pressure forces cannot prevent gravitational structure formation in the plasma epoch because pressures equilibrate in time periods smaller that the gravitational free fall time \((\rho G)^{-1/2}\) on length scales smaller than the Jeans scale, and the Jeans scale in the primordial plasma is larger than the Hubble scale of causal connection \(L_H = ct\), where \(c\) is light speed and \(t\) is time. Therefore, if gravitational forces exceed viscous and turbulence forces in the plasma epoch at scales smaller than \(L_H\) then gravitational structures will develop, independent of the Jeans criterion. Only a very large diffusivity of the plasma \((D \gg \nu)\) could interfere.

The diffusion velocity is \(D/L\) for diffusivity \(D\) at distance \(L\) and the gravitational velocity is \(L\rho^{1/2}G^{1/2}\). The two velocities are equal at the diffusive Schwarz length scale

\[
L_{SD} \equiv \left[D^2/\rho G\right]^{1/4}. \tag{2}
\]

Thus very weakly collisional particles such as the hypothetical cold-dark-matter (CDM) material cannot form potential wells for baryonic matter collection because the particles have large diffusivity and will disperse, consistent with observations (Sand et al. 2002). Diffusivity \(D \approx V_p \times L_c\), where \(V_p\) is the particle speed and \(L_c\) is the collision distance. Because weakly collisional particles have large collision distances with large diffusive Schwarz lengths the non-baryonic dark matter (possibly neutrinos) is the last material
to fragment by self gravity and not the first as assumed by CDM cosmologies. The first structures occur as proto-supercluster-voids in the baryonic plasma controlled by viscous and weak turbulence forces, independent of diffusivity \( D \approx \nu \). The CDM seeds postulated as the basis of CDMHCC never happened because \( (L_{SD})_{NB} \gg ct \) in the plasma epoch.

The baryonic matter is subject to large viscous forces, especially in the hot primordial plasma and gas states existing when most gravitational structures first formed. The viscous forces per unit volume \( \rho \nu \gamma L^2 \) dominate gravitational forces \( \rho^2 GL^4 \) at small scales, where \( \nu \) is the kinematic viscosity and \( \gamma \) is the rate of strain of the fluid. The forces match at the viscous Schwarz length

\[
L_{SV} \equiv (\nu \gamma / \rho G)^{1/2},
\]

which is the smallest size for self gravitational condensation or void formation in such a flow. Turbulent forces may require even larger scales of gravitational structures. Turbulent forces \( \rho \varepsilon^{2/3} L^{8/3} \) match gravitational forces at the turbulent Schwarz scale

\[
L_{ST} \equiv \varepsilon^{1/2} / (\rho G)^{3/4},
\]

where \( \varepsilon \) is the viscous dissipation rate of the turbulence. Because in the primordial plasma the viscosity and diffusivity are identical and the rate-of-strain \( \gamma \) is larger than the free-fall frequency \( (\rho G)^{1/2} \), the viscous and turbulent Schwarz scales \( L_{SV} \) and \( L_{ST} \) will be larger than the diffusive Schwarz scale \( L_{SD} \), from (2), (3) and (4).

Therefore, the criterion for structure formation in the plasma epoch is that both \( L_{SV} \) and \( L_{ST} \) become less than the horizon scale \( L_{H} = ct \). Reynolds numbers in the plasma epoch were near critical, with \( L_{SV} \approx L_{ST} \). From \( L_{SV} < ct \) and (3), gravitational structures first formed when \( \nu < c^2 t(t^2 \rho G) \approx c^2 t \) at time \( t \approx 10^{12} \) seconds (Gibson 1996), well before \( 10^{13} \) seconds which is the time of plasma to gas transition (300,000 years). Because the expansion of the universe inhibited condensation but enhanced void formation in the weakly
turbulent plasma, the first structures were proto-supercluster-voids. At $10^{12}$ s

$$(L_{SD})_{NB} \gg L_{SV} \approx L_{ST} \approx 5 \times L_{K} \approx L_{H} = 3 \times 10^{20} \text{m}, \quad (5)$$

where $L_{SD}$ applies to the non-baryonic component and $L_{SV}, L_{ST},$ and $L_{K}$ apply to the baryonic component.

As proto-supercluster fragments formed the voids filled with non-baryonic matter by diffusion, inhibiting further structure formation by decreasing the gravitational driving force. The baryonic mass density $\rho \approx 2 \times 10^{-17} \text{kg/m}^3$ and rate of strain $\gamma \approx 10^{-12} \text{s}^{-1}$ were preserved as hydrodynamic fossils within the proto-supercluster fragments and within proto-cluster and proto-galaxy objects resulting from subsequent fragmentation as the photon viscosity and $L_{SV}$ decreased prior to the plasma-gas transition and photon decoupling (Gibson 2000). As shown in Eq. 5, the Kolmogorov scale $L_{K} \equiv [\nu^3/\varepsilon]^{1/4}$ and the viscous and turbulent Schwarz scales at the time of first structure nearly matched the horizon scale $L_{H} \equiv ct \approx 3 \times 10^{20} \text{m},$ freezing in the density, strain-rate, and spin magnitudes and directions of the subsequent proto-cluster and proto-galaxy fragments of proto-superclusters. Remnants of the strain-rate and spin magnitudes and directions of the weak turbulence at the time of first structure formation are forms of fossil vorticity turbulence (Gibson 1999). Thus, HGT explains galaxy spin alignments and close angular associations with quasars without assuming intrinsic red shifts and mutual ejections.

The quiet condition of the primordial gas is revealed by measurements of temperature fluctuations of the cosmic microwave background radiation that show an average $\delta T/T \approx 10^{-5}$ much too small for any turbulence to have existed at that time of plasma-gas transition ($10^{13}$ s). Turbulent plasma motions are strongly damped by buoyancy forces at horizon scales after the first gravitational fragmentation time $10^{12}$ s. Viscous forces in the plasma are inadequate to explain the lack of primordial turbulence ($\nu \geq 10^{30} \text{m}^2 \text{s}^{-1}$ is required but, after $10^{12}$ s, $\nu \leq 4 \times 10^{26}$, Gibson 2000). Thus the observed lack of plasma
turbulence proves that large scale buoyancy forces and gravitational structure formation must have begun in the plasma epoch.

The gas temperature, density, viscosity, and rate of strain are all precisely known at transition, so the gas viscous Schwarz mass $L_{SV}^3 \rho$ is easily calculated to be about $10^{24}$ kg, the mass of a small planet, or about $10^{-6} M_\odot$, with uncertainty about a factor of ten. From HGT, soon after the cooling primordial plasma turned to gas at $10^{13}$ s (300,000 yr), the entire baryonic universe condensed to a fog of planetary-mass primordial-fog-particles (PFPs). These gas-cloud objects gradually cooled, formed H-He rain, and eventually froze solid to become the baryonic dark matter and the basic material of construction for stars and everything else, about $30 \times 10^6$ rogue planets per star.

The Jeans mass $L_J^3 \rho$ of the primordial gas at transition was about $10^6 M_\odot$ with about a factor of ten uncertainty, the mass of a globular star cluster. Proto-galaxies fragmented at the PFP scale but also at this proto-globular-star-cluster PGC scale $L_J$, although not for the reason given by the Jeans 1902 theory. Density fluctuations in the gaseous proto-galaxies were absolutely unstable to void formation at all scales larger than the viscous Schwarz scale $L_{SV}$. Pressure can only remain in equilibrium with density without temperature changes in a gravitationally expanding void on scales smaller than the Jeans scale. From the second law of thermodynamics, rarefaction wave speeds that develop as density minima expand due to gravity to form voids are limited to speeds less than the sonic velocity. Cooling would therefore occur and be compensated by radiation in the otherwise isothermal primordial gas when the expanding voids approached the Jeans scale. Gravitational fragmentation of proto-galaxies will then be accelerated by radiative heat transfer to these cooler regions, resulting in fragmentation at the Jeans scale and isolation of proto-globular-star-clusters (PGCs) with the primordial-gas-Jeans-mass.

These $10^{36}$ kg PGC objects were not able to collapse from their own self gravity because
of their internal fragmentation at the viscous Schwarz scale to form $10^{24}$ kg PFPs. The fact that globular star clusters have precisely the same density and primordial-gas-Jeans-mass from galaxy to galaxy proves they were all formed simultaneously soon after the time of the plasma to gas transition $10^{13}$ s. The gas has never been so uniform since, and no mechanism exists to recover such a high density, let alone such a high uniform density, as the fossil turbulent density value $\rho \approx 2 \times 10^{-17}$ kg/m$^3$. Young globular cluster formation in BDM halos in the Tadpole, Mice, and Antennae galaxy mergers show that dark PGC clusters of PFPs are remarkably stable structures, persisting without disruption or star formation for more than ten billion years.

3. Stephan’s Quintet: HGT interpretation of HST image

Moles et al. 1997 summarize the data and dynamical status of SQ consistent with standard CDMHC 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). Therefore the cores of SQ galaxies should be deficient in gas and YGCs because they have not had mergers or collisions.

Following standard CDMHC cosmology and N-body computer models, galaxies and clusters of galaxies are formed by hierarchical collisionless clustering due to gravity starting with sub-galaxy mass CDM seeds condensed in the plasma epoch after the big bang. The Jeans 1902 gravitational condensation criterion rules out structures forming in ordinary baryonic matter. CDM seeds are diffusionally unstable from hydro-gravitational theory and their clustering to form galaxies is contrary to observations (Sand et al. 2002). From HGT, both CDMHC cosmology and the Jeans 1902 criterion are fundamentally incorrect and misleading (Gibson 2000). 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. However, we can be sure structure formation occurred in the plasma epoch because buoyancy within self gravitational structure is the only mechanism available to prevent turbulence. Viscous forces were quite inadequate. Fully developed turbulence would have produced $\delta T/T \approx 0.1$ values much larger than the $\delta T/T \approx 0.00001$ values observed in numerous cosmic microwave background studies. From HGT, structure formation first occurred by gravitational fragmentation due to the expansion of space when viscous and weak turbulence forces of the primordial plasma matched 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. The growth of structure was arrested by non-baryonic matter filling the voids between baryonic fragments. This 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 fragmenting proto-supercluster \((10^{47} \text{ kg})\) 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 \(3 \times 10^{20} \text{ m}\) with baryonic density \(2 \times 10^{-17} \text{ kg/m}^3\) and non-baryonic density \(\approx 10^{-15} \text{ kg/m}^3\) decreasing with time and the non-baryonic matter (possibly neutrinos) diffuses to fill the voids and reduce the gravitational forces (Gibson 2000). In Fig. 1a center proto-cluster fragments form and separate, and on the right proto-galaxies fragment just before the cooling plasma turns to gas at 300,000 years \((10^{13} \text{ s})\).

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 \(5 \times 10^{19} \text{ m}\). These fragment into Jeans-mass \((10^{36} \text{ kg})\) proto-globular-cluster (PGC) dense clouds of \((10^{24} \text{ kg})\) 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. The Jeans-mass is relevant, but not for the reasons given by Jeans (1902). 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 \(10^{26} \text{ m}\) due to the stretching of space along a thin square tube of diameter \(\approx 2 \times 10^{21} \text{ m}\) 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 true aspect ratio is that of a sheet of paper or a very long stick of uncooked spaghetti. By perspective, about 1% 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 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 are seen to separate through each other’s halos rather than merge, 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 gas patterns (Gutierrez et al. 2002) observed from broadband R measurements that suggest NGC 7320 has the same origin near NGC 7319. An unidentified galaxy 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 and there is no 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 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.

4. Stephan’s Quintet: HGT interpretation of R and \(H_\alpha\) maps

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 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.

5. 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 in a cluster by gravitational fragmentation of the primordial plasma just before photon decoupling and transition to gas 300,000 years after the big bang. None of the galaxies show evidence of subsequent collisions or mergers. They remained stuck together for 12.9 billion years until 220 million years ago when the uniform expansion of space in the universe finally
overcame gravitational forces and frictional forces of the cluster baryonic-dark-matter halo.

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 Schwarzs 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 \(2 \times 10^{21}\) m, compared with the BDM halo radius of the Tadpole galaxy \(5 \times 10^{21}\) m as shown by HST/ACS images with 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 from HGT that a uniform expansion of the universe stretched the SQ galaxies along a line of sight because of perspective and small transverse velocities resulting from BDM halo gas friction and their sticky beginnings, as shown in Fig. 1b. The common point of origin of the SQ galaxies is confirmed by gas trails in recent R and \(H\alpha\) maps, as shown in Fig. 3 (Gutierrez et al. 2002). Discordant red shifts for aligned quasars and AGN galaxies are also explained using HGT rather than CDMHCC for the same reasons.
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This manuscript was prepared with the AAS \LaTeX{} macros v5.0.
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; eg., 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.
Fig. 2.— Hubble Space Telescope image of Stephan’s Quintet. Dust and star wakes (arrows) are produced as SQ related galaxies gently separate from each other through the cluster baryonic-dark-matter (BDM) halo of PGCs and PFPs, triggering star formation. Star wakes of mergers and collisions are not observed.
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.