Galaxy Mergers in an Evolving Universe
ASP Conference Series, Vol. 477
Wei-Hsin Sun, Kevin Xu, Nick Scoville, and David Sanders eds.

SPH Simulations of Stephan's Quintet

Jeong-Sun Hwang[1,2], Curtis Struck[1], Florent Renaud[3,4], and Philip N. Appleton[5]

[1]*Department of Physics and Astronomy, Iowa State University, Ames, IA 50011, USA*

[2]*School of Physics, Korea Institute for Advanced Study, Seoul 130-722, Korea*

[3]*Observatoire Astronomique and CNRS UMR 7550, Université de Strasbourg, 11 rue de l'Université, F-67000 Strasbourg, France*

[4]*Laboratoire AIM Paris-Saclay, CEA/IRFU/SAp, Université Paris Diderot, F-91191 Gif-sur-Yvette Cedex, France*

[5]*NASA Herschel Science Center (NHSC), California Institute of Technology, Mail code 100-22, Pasadena, CA 91125, USA*

Abstract. We present smoothed particle hydrodynamic models of the interactions in the compact galaxy group, Stephan's Quintet. Adding thermohydrodynamic effects to the earlier collisionless N-body simulations of Renaud et al., we further investigate the dynamical interaction history and evolution of the intergalactic gas of Stephan's Quintet. Specifically, we reproduce the major stellar and gas features of the group and also model the formation of the hot X-ray gas, the group-wide shock, and emission line gas as the result of NGC 7318b colliding with the group. We compare our model results to multi-wavelength observations.

Using the SPH code of Struck (1997), we have constructed numerical models of Stephan's Quintet (hereafter SQ). We ran about 170 runs, testing various interactions hypotheses. In this proceeding, we briefly present our fiducial model and some of the results (Hwang et al. 2011; Renaud et al. 2010).

The initial parameters of the fiducial model are summarized in Table 1. We will henceforth refer to the model galaxies for NGC 7319, 7318a, 7318b (the high-speed intruder), and 7320c as G1, G2, G3, and G4, respectively to avoid confusion between the model galaxies and the real ones. The model is designed (1) to generate the two long tails extending from NGC 7319 toward NGC 7320c simultaneously by a close encounter of G4 with G1, resulting in a thinner and denser inner tail than the outer one and forming a parallel configuration as observed, (2) to have a collision between G2 and G3 relatively far behind the plane of G1, and (3) to make a high-speed collision between G3 and the material found west of G1.

Figure 1 shows the model system at a time near the present (or shortly after the present) when the intruder (G3) has passed the mid-plane of G1 after the strong impact. We think that the fiducial model is generally successful in reproducing the observed H I gas features of SQ (Williams et al. 2002). Specifically, the huge amount of high-v_r gas along the parallel tails, the features looking like SW-arm and SQ-A (see fig. 1 of Hwang et al. 2011), the high- and intermediate-v_r gas to north of the high-speed

Table 1. Initial parameters of the fiducial model

	G1	G2	G3	G4
Halo masses[a] ($\times 10^{10}$ $M_\odot$)	12.6	8.2	7.1	2.4
Halo cutoff radii[b] (kpc)	135.0	55.0	80.0	45.0
Gas disk radii (kpc)	27.0	8.0	16.0	9.0
Stellar disk radii (kpc)	18.0	11.0	11.0	7.0
Gas particle numbers	68,680	6,000	24,000	7,480
Star particle numbers	32,000	11,760	11,760	4,960
disk orientations[c]		180° about x-axis	180° about x-axis	
Initial center positions[d] (x,y,z) (kpc)	(0, 0, 0)	(−70, 10, −20)	(12, 2, −340)	(12.5, −15.3, 15.3)
Initial center velocities[e] (v_x,v_y,v_z) (km s^{-1})	(0, 0, 0)	(110, −27, −72.5)	(20, −7.5, 300)	(35.9, 79.5, −77.5)

[a]The given halo mass is that contained within a halo cut-off radius. Gas and star disk masses are negligible in this model.

[b]The halo cut-off radii for G1, G3, and G4 are set to five times their gas disk radii; for G2, five times its star disk radius. No group halo is applied.

[c]All galaxy disks are initialized in the x-y plane with counter-clockwise directional spins as seen from the positive z-axis and then rotated as necessary. In this model, G1 and G4 are set in the x-y plane with counter-clockwise directional spins, and G2 and G3 are flipped around the x-axis so that they have clockwise directional spins. No additional tilts are applied in this model.

[d]Coordinates are defined in a conventional, right-handed frame, with the origin fixed at the center of G1. The x-y plane is defined as the plane of the sky, and positive z as the direction towards the observer.

[e]Positive z velocities mean motions towards us in the non-inertial reference frame of G1.

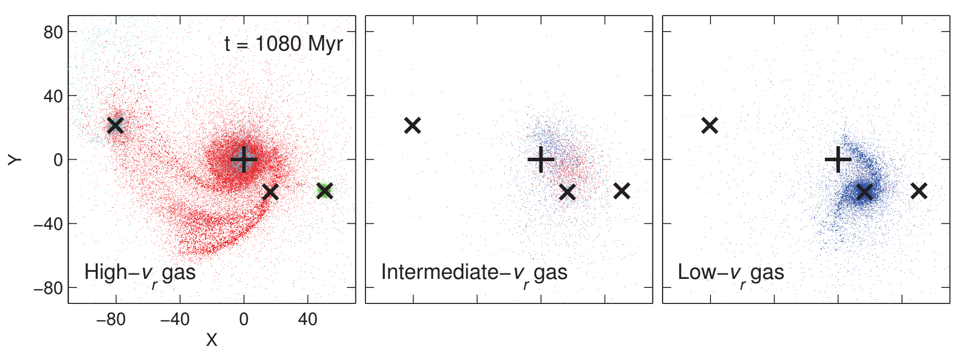

Figure 1. Gas particles of the fiducial model at t = 1080 Myr (since the closest encounter of G4 and G1; in the representative scaling described in Hwang et al. 2011) in three v_r ranges. The left to right panels show the gas particles in high, intermediate, and low v_r ranges, projected on to the x-y plane. Red, green, blue, and cyan dots represent the particles originating from G1, G2, G3, and G4, respectively. The center position of G1 is indicated with a plus sign and those of G2, G3, and G4 with ‘X’s.

intruder and some scattered low-v_r gas to the south-west of the high-speed intruder that were produced in the model resemble more or less the real features.

The fiducial model also shows the shock-heated gas, by the impact of the high-speed intruder with the IGM, in an elongated feature with little star formation (see fig. 8 of Hwang et al. 2011). It is found from the model that a gas bridge is formed in the shock region and particles in the bridge continue to interact for some tens of millions of years after the impact. The full details of our work is described in Hwang et al. 2011.

References

Hwang J.-S., Struck C., Renaud F., Appleton P. N., 2011, MNRAS in press (arXiv:1109.4161)
Renaud F., Appleton P. N., Xu C. K., 2010, ApJ, 724, 80
Struck C. 1997, ApJS, 113, 269
Williams B. A., Yun M. S., Verdes-Montenegro L., 2002, AJ, 123, 2417