Exercise 1, Questions 1 – 3. Answers will vary greatly. The important thing is that students have a reasonable classification system that makes distinctions between different types of galaxies without dividing them into groups that contain only one member.

Exercise 2.

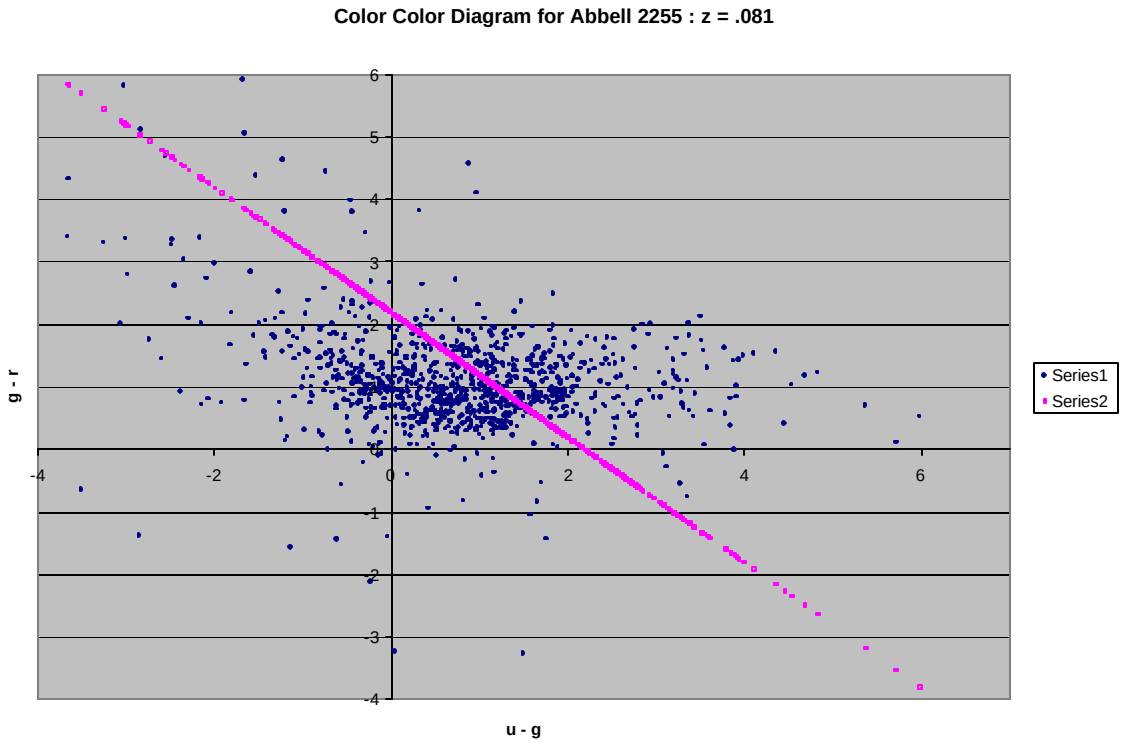
Run	Camcol	Field	Galaxy Type
752	1	244	Sb
94	4	129	SBb
752	1	331	E3 or E4
125	1	321	SB0
756	4	198	Sb or Sc (technically, this galaxy is a transition galaxy from type b to c)
94	2	446	SB
752	1	432	This is an unusual galaxy…it is a transition between barred spiral and spiral, and a transition between a and b. Therefore, it could be Sa, Sb, SBa, or SBb. This will keep them guessing!
752	2	16	Irregular
125	3	285	S0 (easily mistaken for elliptical E0)
125	2	182 (lower left galaxy)	S0 (actually, both galaxies in the image are S0!)
94	3	276 (upper left corner)	E3 (it's just marked E in NED and SIMBAD)
125	3	196 (3 galaxies)	Left galaxy: SO; Center galaxy: E2; Right galaxy: E4
94	3	291	This is a transition galaxy from Sa to Sb
94	1	306	SBb or SBc (transition galaxy)
94	1	317	SBA (some class it as SB0)
94	3	372 (2 nice galaxies)	Left galaxy: Sc; Right galaxy: SBa
125	3	318	SBb (NED lists as transition galaxy between SBb and SBc
125	1	322	Sc
125	1	326	Sa or Sb (transition galaxy)

Many of these galaxies lie between two different types (and some of them are listed as different types in different catalogs… even the professionals don't always agree!

Exercise 3. Answers will vary. Students should recognize that galaxies with similar magnitudes, sizes, and colors are probably part of the cluster. They should select a few galaxies from the cluster and identify their types.

Exercise 4. Answers will vary depending on which galaxies students chose. The more galaxies they select, the more their diagrams will look like the diagram for Exercise 5 below.

Exercises 5-6. The galaxies in Abell 2255 are shown in blue; the separator line is shown in pink.



Question 4. Blue galaxies have are low u –g and g – r values so they are to the lower left. Redder galaxies are to the upper right.

Question 5. Based on work from Exercise 4, students should recognize that elliptical galaxies would be lie to the upper right and spiral galaxies to the lower left.

Exercise 6. See the pink line in Exercise 5.

Question 6. In this sample, about 63% of the galaxies are spiral (late). This is slightly lower than the universe as a whole. This exercise looks at only a small portion of the sky, so this statistical variation should not be a surprising result.

Exercise 7, Questions 7 – 9.

Object ID	Plate Number	Fiber Number	Color (u-r)	Galaxy Type	Emission or Absorption lines
2255031269261392	302	325	1.10	SBc or SBb	Strong H_a,$H_ß$,$H_?$; OII and OIII emission
2255029906702376	277	290	1.45	Sa or SBa	Strong H_a,$H_ß$,weaker $H_?$; strong OII and OIII
2255030989357127	288	492	1.71	SBA	Strong H_a, weaker $H_ß$; weak OII; H&K absorption lines; Mg absorption
2255048446247171	283	565	1.95	SBa	Strong H_a, weak $H_ß$; strong OII; weak SII; H&K absorption; OIII absorption
1970862258258031	398	82	2.21	SBO	Strong H_a, weak $H_ß$; weak OII; H&K absorption; Mg and G band absorption
2255030731145307	300	592	2.50	SO or EO	H_a and OII emission; lots of metal absorption
1970729388998708	398	113	2.7	E3	Little emission; lots of metal absorption, especially H&K, G band, Mg, & Na
1970863334096941	400	608	2.88	E1 or E2	Lots of metal absorption, especially H&K, G band, Mg, & Na
2255030731931843	301	514	3.05	E 1 or E2	Strong metal absorption, especially H&K, G band, Mg, & Na
1970729661235319	403	422	3.4	E2	Strong metal absorption, especially H&K, G band, Mg, & Na; peak noticeably red
2255029916729537	289	43	3.79	E7	OII & NII emission; lots of metal absorption

Question 10. The students should notice that as they move down the list, the galaxies get redder. Some of the galaxies are visually small and difficult to classify. Students may also notice an S0 galaxy right at the separator. S0 is a transition between spirals and ellipticals, so its presence here is expected.

Students should notice that there are few hydrogen emission lines in ellipticals. This is due to lack of HII regions that spawn star formation. Ellipticals are dominated by the metal absorption lines of old stars. A redshift is visible in some of the galaxies.

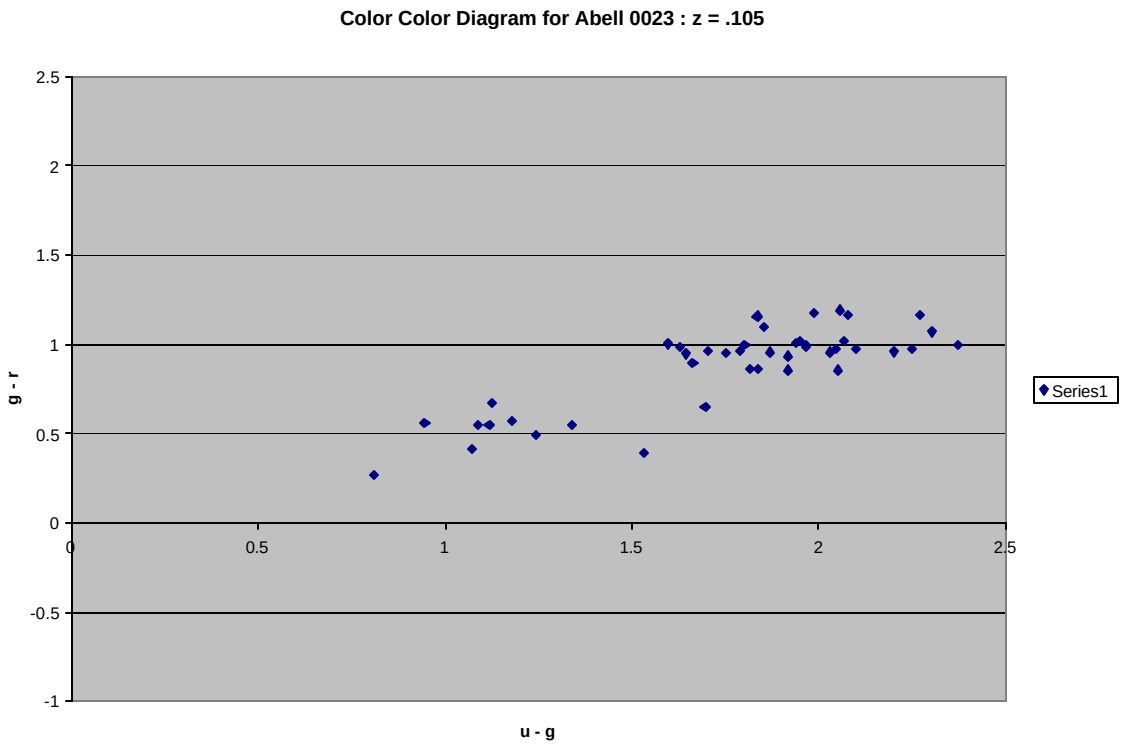
Supplemental Exercise 1. This exercise should get students acquainted with the GalCrash Java applet.

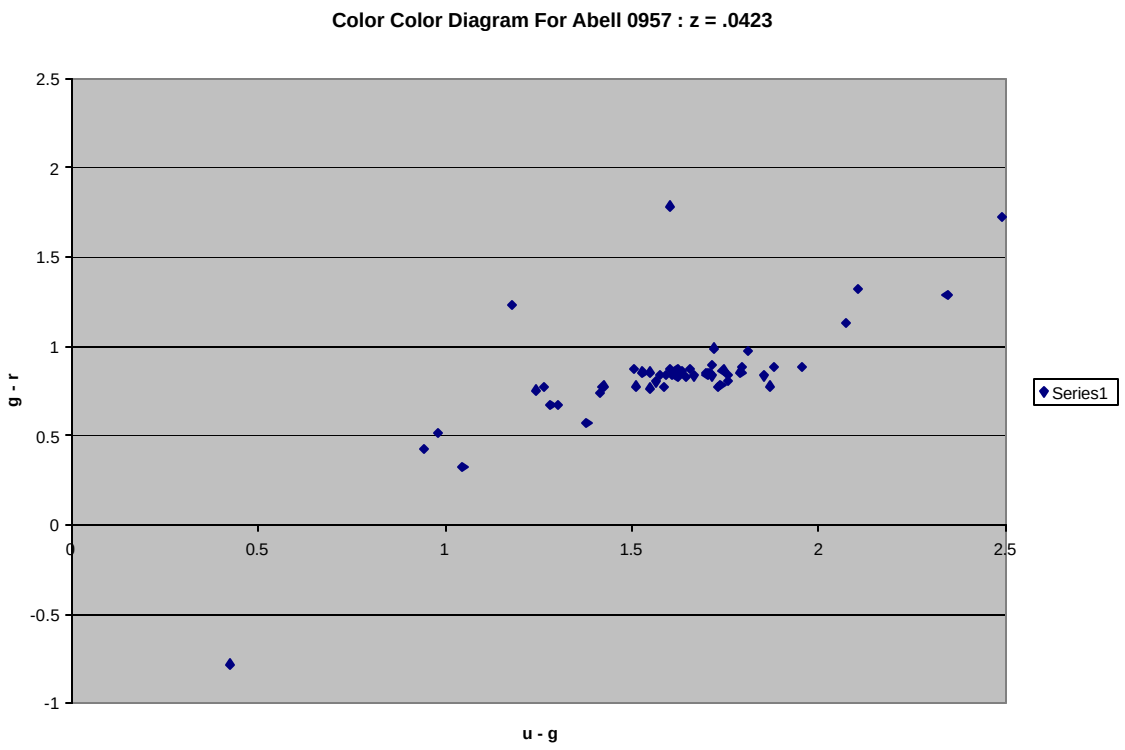
Supplemental Question 1. The most important parameter in galaxy collisions is the ratio between the masses of the colliding galaxies. The initial separation between the galaxies also affects how the galaxies collide.
The presence of dynamical friction also has a tremendous influence on the results of the simulation. With friction turned on, the galaxies almost always merge into one another.

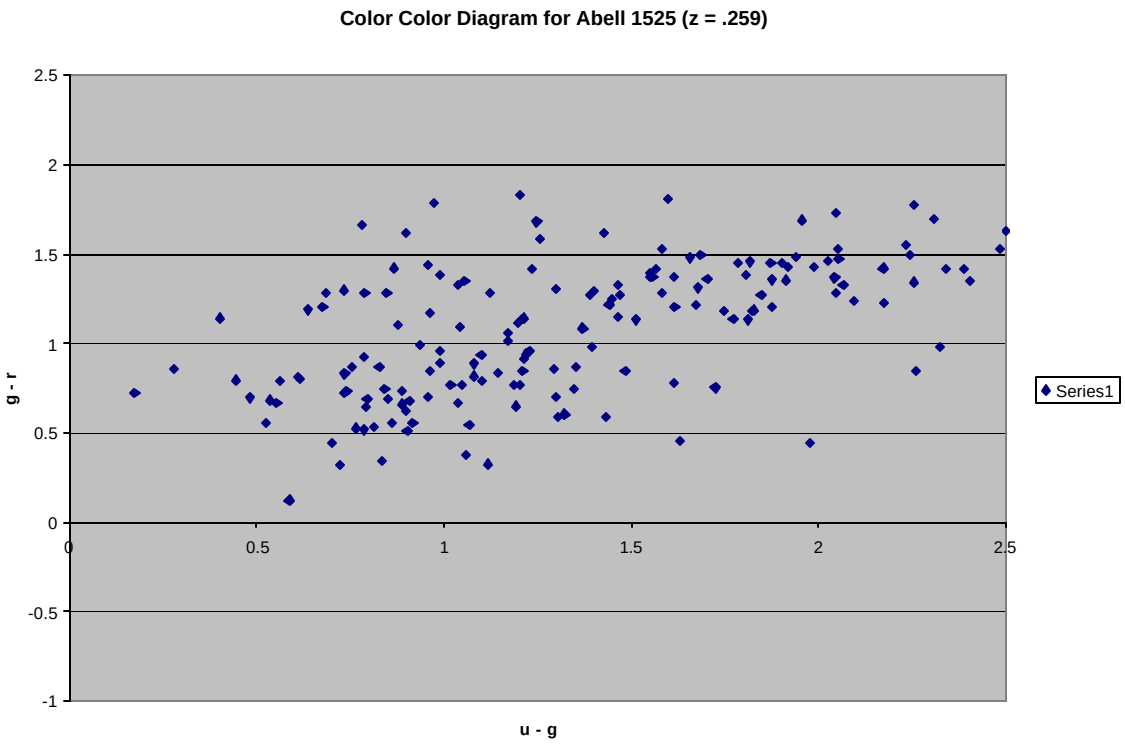
Supplemental Question 2. It is indeed possible to get results from GalCrash that look like actual colliding galaxies. You can get results similar to those shown in the picture by setting Red Theta = -5.0 degrees, Green Theta = -25.0 degrees, peri = 10.5 kpc, and number of stars = 750. Center the simulation on the green galaxy, then run for about 350 million years.

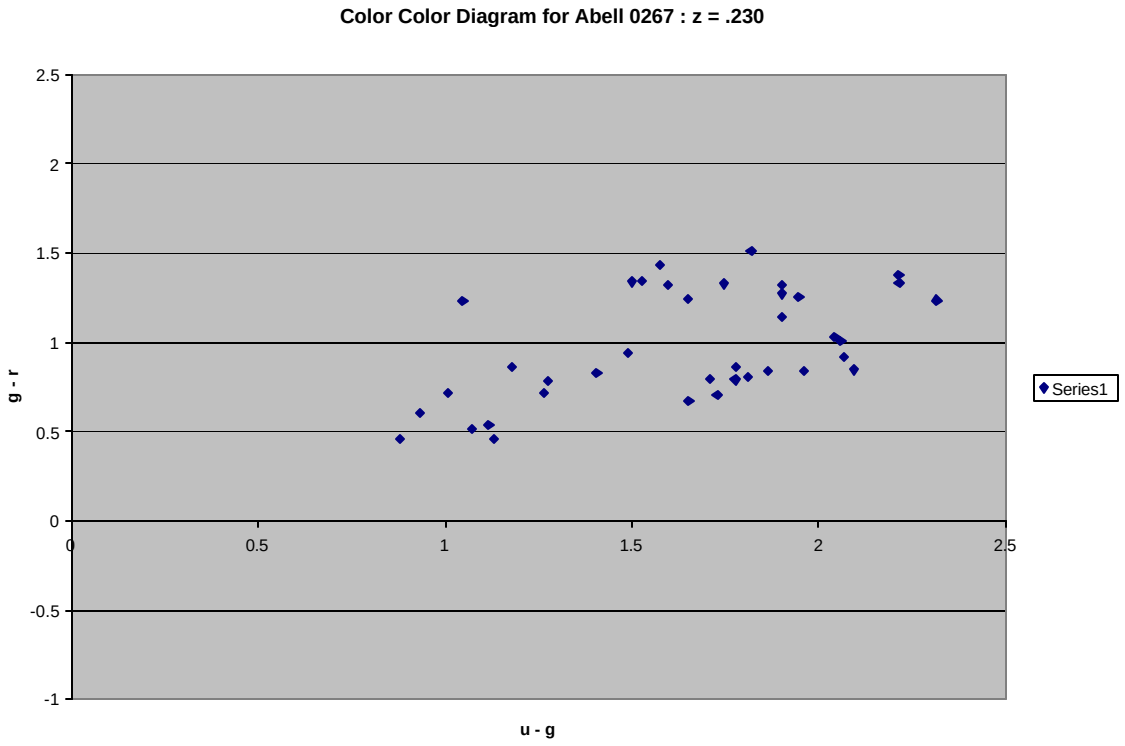
Exercise 6. This is the research challenge for this project, and it is one of the more difficult research challenges on SkyServer. Students can look up the galaxy clusters in SIMBAD, which will tell them the magnitude of the 10th brightest galaxy and how many galaxies are in the cluster. From this information, they can eliminate bright foreground and dim background galaxies. For example, if the 10th brightest galaxy has a magnitude of 15, and they see the 20th brightest galaxy in their data has a magnitude of 15, they can surmise that the 10 brightest galaxies in their data are probably foreground galaxies. They can then count down to the dimmest galaxy in their cluster.

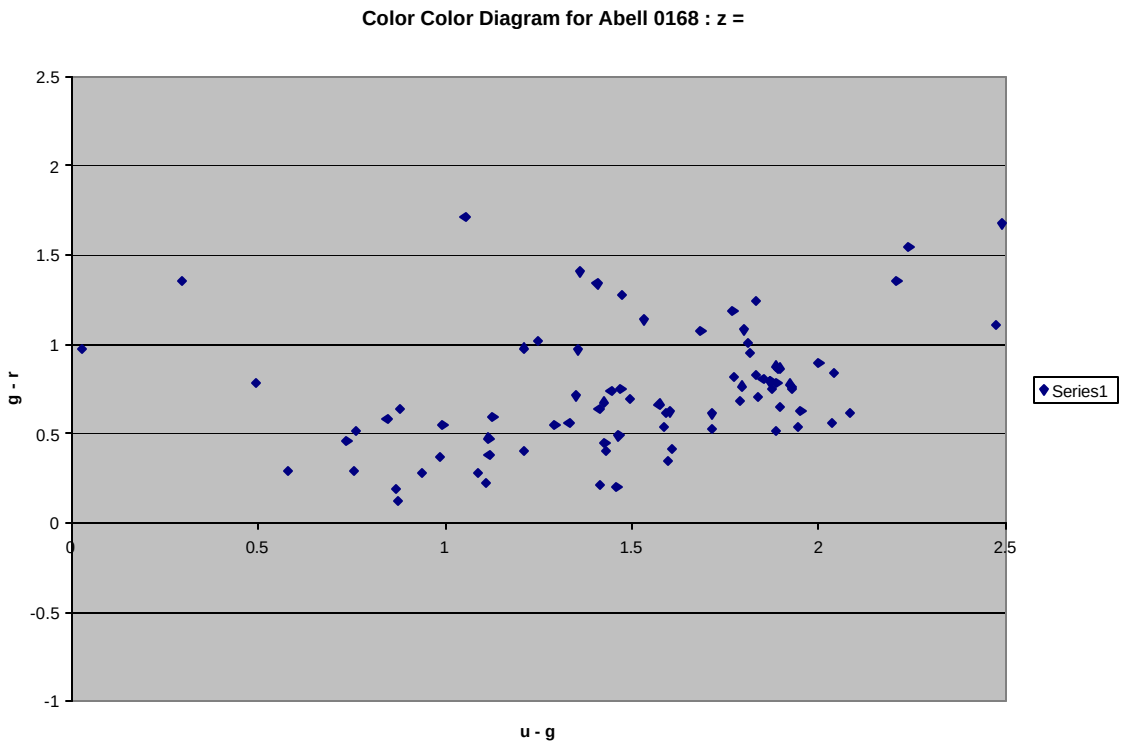
The next three pages show some sample diagrams for this exercise.


Color Color Diagram for Abell 0023 : z = .105
2.5
2
1.5
1
0.5
0
-0.5
-1
g - r
0
0.5
1
1.5
2
2.5
u - g
Series1


Color Color Diagram For Abell 0957 : z = .0423
2.5
2
1.5
1
0.5
0
-0.5
-1
g - r
0
0.5
1
1.5
2
2.5
u - g
Series1


Color Color Diagram for Abell 1525 (z = .259)
2.5
2
1.5
1
0.5
0
-0.5
-1
g - r
0
0.5
1
1.5
2
2.5
u - g
Series1


Color Color Diagram for Abell 0267 : z = .230
2.5
2
1.5
1
0.5
0
-0.5
-1
g - r
0
0.5
1
1.5
2
2.5
u - g
Series1


Color Color Diagram for Abell 0168 : z =
2.5
2
1.5
1
0.5
0
-0.5
-1
g - r
0
0.5
1
1.5
2
2.5
u - g
Series1