**Overview & Instructions for “Balloon / Stellar End Products” Activity.**

Activity presented at McDonald Observatory teacher workshops, based on activity: “By-products of Stellar Death: Neutron Stars and Black Holes” by Investigating Astronomy, Its About Time.

*Of all objects in the universe, neutron stars, pulsars, and black holes are some most intriguing and least understood. In this activity students will model the process of how neutron stars and black holes (stellar end products) are formed.*

Part 1: Modeling the Death of a Star

1. Make a model of a star by blowing up a balloon and tying off the end.
* The balloon represents a star.
* The air in the balloon represents the heat pressure of the fusion process – the method by which mass is supported in ordinary stars.
1. Find the radius (R) of the balloon.
	* Measure the diameter of the balloon in centimeters with a metric ruler in two difference directions and average your two measurements.
	* Divide this number by two to get the radius (R) of the balloon.
2. Compute the volume (V) of the balloon using the formula V = $\frac{4πR^{3}}{3}$
3. Make a data table similar to the one below and record your values for R and V into the table.

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| OBJECT | Mass (g) | Radius (cm) | Volume (cm3) | Density (g/cm3) |
| Balloon Star |  |  |  |  |
| Foil Core |  |  |  |  |
| Foil White Dwarf |  |  |  |  |
| Foil Iron Core |  |  |  |  |
| Foil Neutron Star |  |  |  |  |

1. Wrap a piece of aluminum foil around your balloon to represent the core of your balloon star.
2. Use a balance or scale to find the mass of the star/core in grams.
3. Compute the density of the stellar core using the formula, Density = Mass / Volume.
4. Record in your data table, the volume and density of the balloon model.
5. Remove the aluminum foil from the balloon, and crush the aluminum foil (very gently) into a smaller ball. At this point don’t fully crush your aluminum foil, only make it into a slightly smaller ball.
	* The new stellar core represents (very roughly) what is happening inside a star as it evolves into a white dwarf (this will happen for lower mass stars like our Sun).
	* The force holding up the mass of the star is the repulsion of close-packed electrons, a condition called electron degeneracy. This process never happens on Earth because no machine is powerful enough to exert such enormous force.
6. Find the volume and density of the new stellar core (foil white dwarf core) and record the values in your data table. Note: what variable should remain the same at this stage, even though the size and volume are getting smaller? (mass of core).
7. Use your hands and compress the aluminum into the smallest ball you can.
	* This represents the star’s iron core that cannot be compressed any smaller. This would happen for star’s that are originally 8 times or greater more massive than the Sun.
8. Find the volume and density of your compressed stellar core (Foil Iron Core) and record the values in your data table.
9. Pop your balloon – your star has just gone supernova! Bring your foil core to your teacher who will use a hammer to crush it down as far as possible.
	* This core model simulates (very, very roughly) the further compression of a massive star’s core as it is crushed in a supernova to a tiny neutron star. This core is held up by the nuclear force due to a closely packed ball of neutrons, a condition called neutron degeneracy.
10. Find the volume and density of the new stellar core model (Foil Neutron Star) prepared by your teacher.
11. Graph your data, Density vs. Volume. Decide which variable should go on the x-axis and which should go on the y-axis.
12. As an extension discuss a black hole. What happens to the density of a star as its volume reaches zero – a moment that marks the formation of a black hole?