## Index Card: Sagan Video

(This is an individual activity. Write your name and **UT EID and responses** on lined side of the card.)

We watched a couple of excerpts from Episode 9 of Carl Sagan's "Cosmos" series, addressing the synthesis of elements in stars, and how they age and die.

What did you think of this video? Was it worth your time to view it in class? What did you like best/least? State one or two things you learned or understood better, after watching it.

## General Reaction

The overwhelming majority of the class enjoyed the video and thought it was worthwhile watching it.

- It was … "helpful, easy to understand … engaging … visuals are helpful … videos add variety to the lecture."
- Sagan repeated points explained in lecture. (Note: This was *deliberate*.) This can be "a good review" or not worthwhile, but the majority of students found it useful. (Expect more video clips that illustrate & reinforce!)
- "It seemed outdated… melodramatic … a bit cheesy" The hairstyle, wardrobe, and visuals might be old-fashioned, but the content is still valid and current.



## Major Points Learned/Understood

- "Nuclear forces help overcome the repulsion of protons and neutrons. [Only protons; neutrons have no charge!] Fusion requires extremely high temperatures."
- "…[before] the death of the Sun, it will become a red giant, large enough to consume the inner part of our Solar System."
- "…in 5 billion years the Sun will explode…" Not really. It will slowly *expand,* over a period of millions of years.
- "A star has three different ways it can die..[which] depends on the mass of the star: as a white dwarf, black hole, or red giant." The third possibility is as a neutron star. The red giant stage is part of the sequence that leads to a white dwarf.
- I didn't realize that all the elements are just helium added to more helium." They aren't. In a part you didn't view, Sagan pointed out that He-built nuclei are the most common ones.



## Confusions

- "Every time a proton or neutron is added or subtracted [from a nucleus], a new element is formed." For any atomic nucleus, the element is determined strictly by the ***number of protons***. When a proton is added or subtracted, the element changes, but when the number of neutrons changes, you simply have a different **isotope** of the same element.
- A number of students confused nuclear fusion with the formation of molecules. These are ***different*** phenomena. Molecules are held together by *chemical bonds* between electrons and positively charged nuclei; this is due to the *electromagnetic force*. Heavy nuclei are created when the strong nuclear force (illustrated by Sagan as "hooking" fingers together) overcomes the mutual repulsion of the protons. Molecules form at *low* temperatures, whereas nuclear fusion requires *extremely high* temperatures and densities.

# Clarifications

- “Hydrogen and helium from the Sun could be the ancestors of all the elements found on Earth and in our Solar System.” The Earth and other planets formed at the same time as the Sun, so our Sun cannot be the _direct source_ of local heavy elements. (Also, some of them are not made by low-mass stars like the Sun.) The heavy atoms in the planets were made in stars that lived *and died before* the Solar System formed.
- “Everything about the life of a star depends on its initial mass, so a star with less mass becomes a red giant faster than a star like the Sun.” The **opposite** is true. As we discussed on Sep. 27, lower-mass stars age *more slowly* than higher mass stars. (This is the basis of the Main Sequence turn-off method of getting ages for star clusters – see Essay 5 on Exam 1.)



# Clarifications

- “A white dwarf is a star that has collapsed until it is held together by electron force.. [and] a neutron star is held together by nuclear force.” You have things backwards! Stars are held _together_ by gravity, which is the inward/downward force. A white dwarf (also, a brown dwarf) is held up ***against*** gravity by the quantum pressure of electrons against each other, known as electron degeneracy pressure. In a neutron star, it’s the similar degeneracy pressure of neutrons that balance gravity, and in a normal star, it’s thermal pressure.
- “A black hole is basically a star with no mass.” This is exactly wrong. A black hole is basically a star with a specific mass but almost no other distinguishing properties! (See next slide.)



# Clarifications

- Sagan said: a 1 $M_\odot$ star becomes a white dwarf, if it has 2 $M_\odot$ it becomes a neutron star, and if it has 3 $M_\odot$, it becomes a black hole. This is, strictly speaking, correct. However, he was talking about the mass of the star’s core, which is left behind after a planetary nebula or supernova event. This is not the same – is usually considerably *smaller* – than the **initial** mass.
- A black hole has “no size at all.” Some of you interpreted “size” as mass. I’m not sure why, because he had just compared the sizes – meaning radii – of a white dwarf to the Earth, and a neutron star to a city. Sagan meant that a black hole has no *physical* surface or radius. It is important to keep in mind whether you mean radius or mass, when you say “size.” In Ast 309N, “size” always means radius or diameter.