

Introductory Astronomy

Homework 9: The Life of the Sun Not to be handed in. Homework solutions are posted already.

1. The life history of our own star, the Sun, is known to us by:
 - a) direct observations of all of its stages.
 - b) direct observations of most of its stages plus observations of other stars in all their stages and modeling.
 - c) direct observations of its current stage plus observations of other stars in all their stages and modeling.
 - d) modeling alone.
 - e) sheer guesswork.
2. The interstellar medium (ISM) consists of:
 - a) planets.
 - b) molecular clouds only.
 - c) stars.
 - d) dust only.
 - e) gas and dust.
3. In modern astronomy, a nebula (plural nebulae) is a:
 - a) cloud of a gas in space.
 - b) large main sequence star.
 - c) small main sequence star.
 - d) bright star.
 - e) young star.
4. The dense, cold component of the interstellar medium from which stars are believed to form is made of:
 - a) H II (ionized hydrogen) regions.
 - b) white dwarfs.
 - c) protostars.
 - d) Lyman-Alpha forests.
 - e) molecular clouds.
5. The composition of molecular clouds in the interstellar medium is dominated by:
 - a) carbon dioxide.
 - b) molecular oxygen only.
 - c) helium gas only.
 - d) amino acids.
 - e) molecular hydrogen and helium gas.
6. Molecular clouds are probably about 1 per cent dust by mass.
 - a) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
 - b) The dust is **VERY IMPORTANT** to these clouds. It is **COMPLETELY TRANSPARENT** to visible and ultraviolet light, and allows plenty of hard electromagnetic radiation into the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
 - c) The dust is **COMPLETELY UNIMPORTANT** to these clouds. True, the dust is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains,

meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.

- d) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.
 - e) The presence of this dust is just coincidental. It just happens that where there is dust there are molecular clouds, and where there is no dust there aren't. Things could be entirely otherwise; they just aren't.
7. Interstellar dust probably varies widely in composition, size scale, and structure. But there some ideas about typical dust that are generally accepted.
- a) Although size scale probably varies widely, a typical dust grain may be of order $1\ \mu\text{m} = 10^{-6}\ \text{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\ \mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4 , and NH_3 . The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **VOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **NONVOLATILES** condense out on the cores.
 - b) Although size scale probably varies widely, a typical dust grain may be of order $1\ \mu\text{m} = 10^{-6}\ \text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\ \mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4 , and NH_3 . The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.
 - c) Although size scale probably varies widely, a typical dust grain may be of order $1\ \mu\text{m} = 10^{-6}\ \text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\ \mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4 , and NH_3 . The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **NONVOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **VOLATILES** condense out on the cores.
 - d) Although size scale probably varies widely, a typical dust grain may be of order $1\ \mu\text{m} = 10^{-6}\ \text{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\ \mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4 , and NH_3 . The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.

- e) The dust is found under sofas and on other untouched surfaces. It gets there by settling out the air. One often sees dust in air reflecting bright sunlight.
8. Star formation in a dusty molecular cloud probably requires some triggering event to initiate the collapse to dense cores that will become stars. Two possible trigger mechanisms are:
- SUPERNOVAE** which compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
 - WHITE DWARFS** which ram into and thereby compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
 - WHITE DWARFS** which ram into and thereby compress molecular clouds and **PROTOSTAR-PROTOSTAR COLLISIONS** which also compress the molecular clouds.
 - WHITE DWARFS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.
 - WHITE HOBBITS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.
9. In a **FREE-FALL** contraction of part of molecular cloud:
- the part starts fall to toward a high density point because of gravitational attraction. Pressure forces slow the fall from the beginning.
 - the part starts fall to toward a high density point because of gravitational attraction. Pressure forces are negligible in slowing the fall because it is a free-fall contraction.
 - the entire molecular cloud collapses to form a black hole.
 - the part collapses to form a black hole.
 - planetesimals collide and break apart.
10. A protostar is sometimes conveniently defined to be a:
- star that can no longer burn hydrogen to produce thermal energy.
 - white dwarf.
 - star hot enough to radiate in the infrared, but not yet sufficiently hot for nuclear burning.
 - molecular cloud that will become a star.
 - giant molecular cloud that will become a star.
11. The contraction of a protostar is halted eventually by:
- the thermal energy generated by the contraction which **DECREASES** the gas pressure inside the protostar.
 - the thermal energy generated by the contraction which **INCREASES** the gas pressure inside the protostar.
 - the action of magnetic fields.
 - the action of the dynamo effect.
 - the heat generated by the turning on of nuclear burning which **INCREASES** the gas pressure inside the protostar.
12. "Let's play *Jeopardy!* For \$100, the answer is: They are relatively thin, round objects consisting of gas and/or dust and/or particles that orbit in the same direction some large astro-body in essentially circular orbits of varying radii."

What are _____, Alex?

- a) CDs b) planets c) disks d) satellites e) projectiles

13. During a star's **MAIN SEQUENCE LIFE**, the star is relatively unchanging. But, of course, it is actually changing slowly on the road to its demise. The key change is that:
- carbon dioxide (CO_2) is being expelled by the star's wind.
 - molecular nitrogen (N_2) is being expelled by the star's wind.
 - hydrogen fuel is being exhausted in its core.
 - hydrogen fuel is being exhausted on its surface.
 - helium fuel is being exhausted in its core.
14. Most nuclear-burning stars are main sequence stars. The reason for this is that the main sequence phase of the nuclear-burning life of star of any mass is the:
- shortest phase.
 - most popular phase.
 - wettest phase.
 - longest phase.
 - darnest phase.
15. At the time the Sun first became a main sequence star, its luminosity was probably _____ than at present.
- 30 % greater
 - 100 % greater
 - 50 times greater
 - 30 % lower
 - 100 % lower
16. The end of a star's **MAIN SEQUENCE LIFE** (not its nuclear burning life) comes when it has:
- exhausted the hydrogen fuel in its corona.
 - exhausted the hydrogen fuel in its core region.
 - become a white dwarf.
 - become a green dwarf.
 - exhausted the hydrogen fuel in its sunspots.
17. After the end of its main sequence lifetime the Sun will probably go through the following phases in order:
- red giant, helium flash (a very short stage), horizontal branch star, green giant, planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
 - red giant, helium flash (a very short stage), horizontal branch star, jolly green giant, planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
 - red giant, helium flash (a very short stage), vertical branch star, second red giant (i.e., asymptotic red giant), cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
 - red giant, helium flash (a very short stage), horizontal branch star, second red giant (i.e., asymptotic red giant), planetary/pre-white dwarf, white dwarf, black dwarf (very far in the future).
 - red giant, Larry, Curly, Moe, black dwarf (very far in the future).
18. Lower mass stars (i.e., those which had main sequence mass $\lesssim 8M_\odot$) when burning helium to carbon and oxygen in their **CORES** are called _____ stars.
- red giant
 - supergiant
 - horizontal branch
 - vertical branch
 - oblique branch
19. Lower mass stars (i.e., those which had main sequence mass $\lesssim 4M_\odot$) when burning helium to carbon and oxygen in a shell around an inert carbon-oxygen core, but before they have lost a lot of mass in helium shell flashes, are called _____ stars.
- red dwarf
 - asymptotic giant branch (AGB)
 - horizontal branch
 - vertical branch
 - oblique branch
20. If in its AGB (asymptotic red giant) phase (or 2nd red giant phase), the Sun has expanded and enveloped the Earth, the Earth will:

- a) very quickly collapse to a black hole.
 - b) become a red giant star.
 - c) spiral into the deeper layers of the Sun because of the drag forces of the Sun's outer layers. There the Earth will be totally vaporized. "So the glory of this world passes away": *Sic transit gloria mundi*.
 - d) gain escape velocity and be ejected from the solar system because of the drag forces of the Sun's outer layers.
 - e) implode to form a protostar.
21. "Let's play *Jeopardy!* For \$100, the answer is: These short-time scale episodes of explosive helium shell burning in late stellar evolution eject material that become planetary nebulae."
- What are _____, Alex?
- a) hydrogen shell flashes
 - b) helium shell flashes
 - c) supernovae
 - d) hypernovae
 - e) novae
22. A planetary nebula is:
- a) a cloudy **planet**.
 - b) a cloud that will coalesce into a **planet**.
 - c) a shell of gas thrown off by a dying star before it becomes a **protostar**.
 - d) a shell of gas thrown off by a dying star before it becomes a **white dwarf**.
 - e) a shell of gas thrown off by a dying star before it becomes a **galaxy**.
23. White dwarfs are:
- a) the compact remnants of stars. They are **NOT** burning nuclear fuel. They are **COOLING DOWN** forever.
 - b) giant red stars.
 - c) the compact remnants of stars. They are **STILL** burning nuclear fuel.
 - d) the compact remnants of stars. They are **NOT** burning nuclear fuel. But they are **HEATING UP** forever.
 - e) the compact remnants of stars. They are **NOT** burning nuclear fuel. They have **NEVER** been observed: they are merely predicted theoretically.
24. A black dwarf is:
- a) a black hole.
 - b) a protostar hidden in a molecular cloud.
 - c) a protostar after emerging from its cocoon of gas and dust.
 - d) what a white dwarf becomes when it has cooled off to near absolute zero temperature.
 - e) a shell of gas thrown off by a dying star before it becomes a galaxy.