Introductory Astronomy

Homework 21: Star Formation Not to be handed in. Homework solutions are posted already.

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040 qmult 00110 1 4 3 easy deducto-memory: life history of stars
Extra keywords: Sunlife

1. The life history of stars is known to us by:

   a) direct observations of the evolution of individual stars from the beginning of formation to final demise.
   b) direct observations of the evolution of individual stars from the beginning of formation to final demise plus modeling.
   c) direct observations of many stars at different stages of their evolution, some episodes of rapid individual star evolution, and modeling.
   d) by modeling alone.
   e) by sheer guesswork.

   SUGGESTED ANSWER: (c) We only directly observe stars at a single stage in their evolution or in some episodes of rapid evolution: e.g., when they go supernovae or have some other explosive event.

   Wrong answers:
   e) "Sheer" and "guesswork" are correctly spelt anyway.

   Redaction: Jeffery, 2001jan01

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040 qmult 00200 1 1 5 easy memory: interstellar medium (ISM) defined 1
Extra keywords: CK-299,321, Sunlife

2. The interstellar medium (ISM) consists of:

   a) planets. b) molecular clouds only. c) stars. d) dust only. e) gas and dust.

   SUGGESTED ANSWER: (e)

   Wrong answers:
   a) As Lurch would say: "Aaaarh."

   Redaction: Jeffery, 2001jan01

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040 qmult 00310 1 4 1 easy deducto-memory: nebula defined
Extra keywords: CK-302,321, Sunlife

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.

   SUGGESTED ANSWER: (a) There are many kinds of nebulae: e.g., emission, dark, supernova remnant, reflection, and spiral nebulae: the last one is just a historical name since the spiral nebulae are spiral galaxies and not clouds, but before they were known to be galaxies were called nebulae because they looked like clouds to telescopic observers.

   Wrong answers:
   e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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040 qmult 00320 1 1 5 easy memory: molecular cloud and stars
Extra keywords: CK-321, Sunlife

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.

   SUGGESTED ANSWER: (e) See Se-220. The molecular clouds don't always have to be giant molecular clouds: are they usually giant molecular clouds?

   Wrong answers:
   d) Some of these critters probably do end up helping to make stars.

   Redaction: Jeffery, 2001jan01

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040 qmult 00330 2 1 5 moderate memory: molecular cloud composition
Extra keywords: CK-300, Sunlife

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.

   SUGGESTED ANSWER: (e) Hydrogen and helium dominate the composition of the universe and a molecular cloud should have molecules. Zeilik p. 332 confirms that the hydrogen in molecular clouds is molecular hydrogen.

   Wrong answers:
   a) Carbon dioxide is an important tracer of molecular clouds, but it is a minority species.

   Redaction: Jeffery, 2001jan01

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040 qmult 00410 3 4 1 tough deducto-memory: molecular clouds and their dust
Extra keywords: Sunlife

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 arn't. Things could be entirely otherwise; they just arn't.

SUGGESTED ANSWER: (a) The problem discusses details that weren't and needn't be emphasized in class. But it shows who's thinking. See Se-212 and Zeilik p. 333, 337.

Wrong answers:

b) Hard radiation tends to break up molecules, whose bonds are not that robust. Thus the premise and conclusion of the answer disagree.

c) No, dust is important and molecular clouds and dust usually go together. But there can be dust without molecules and the reverse is probably true. But giant molecular clouds probably always have a lot of dust.

d) No, there arn't molecular clouds where one can see the star formation process in the visible: it seems to be always dust-shrouded.

e) Coincidences due happen, but modern science always suspects (and sometimes wrongly) that behind any seeming coincidence lies a a relationship.

Redaction: Jeffery, 2001jan01

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040 qmult 00420 2 4 3 moderate deducto-memory: molecular cloud dust described

Extra keywords: Sunlife

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 $1\,\mu\text{m} = 10^{-6}$ m in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu$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 $1\,\mu\text{m} = 10^{-6}$ m in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu$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 the reflecting bright sunlight.

SUGGESTED ANSWER: (c) See Zeilik p. 336–337.

Wrong answers:

a) Volatile and nonvolatile mix-up.

b) Volatile and nonvolatile mix-up. If it forms in a black hole, it doesn't get out. By the by, a scot is an archaic term for a payment or a tax derived from Scandinavian languages: it has nothing to do with laddies and lassies in kilts.

d) If it forms in a black hole, it doesn't get out.

e) This is terrestrial dust. I wonder what terrestrial dust is made of. Probably pretty various although some has to be silicates.

Redaction: Jeffery, 2001jan01

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040 qmult 00710 2 4 2 moderate deducto-memory: free-fall molecular cloud

Extra keywords: Sunlife

8. In a **FREE-FALL** contraction of part of molecular cloud:

a) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces slow the fall from the beginning.

b) 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.

c) the entire molecular cloud collapses to form a black hole.

d) the part collapses to form a black hole.

e) planetesimals collide and break apart.

SUGGESTED ANSWER: (b)

Wrong answers:

e) The planetesimals are a much later stage in solar system formation.

Redaction: Jeffery, 2001jan01

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040 qmult 00720 1 4 1 easy deducto-memory: dense core defined sort of
Extra keywords: CK-303,321, Sunlife

9. The collapsing dense regions that develop into stars and initially have temperatures of order 10 K are called:

a) dense cores. b) dilute cores. c) main sequence stars. d) white dwarfs. e) rotten cores.

SUGGESTED ANSWER: (a)

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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040 qmult 00800 2 4 3 moderate deducto-memory: protostar defined
Extra keywords: CK-303 but no mention of IR part, Sunlife

10. A protostar is sometimes conveniently defined to be a:

a) star that can no longer burn hydrogen to produce thermal energy.
b) white dwarf.
c) star hot enough to radiate in the infrared, but not yet sufficiently hot for nuclear burning.
d) molecular cloud that will become a star.
e) giant molecular cloud that will become a star.

SUGGESTED ANSWER: (c) Se-222, gives this definition and FK-450 implicitly agrees. He calls the protostar a prestellar object, but that seems too convoluted for me. But the term is used loosely in astronomy I think.

Wrong answers:
e) A white dwarf is at the far end of stellar evolution.

Redaction: Jeffery, 2001jan01

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040 qmult 00810 2 4 5 moderate deducto-memory: protostar contraction 1
Extra keywords: FK-451 agree with this, Sunlife

11. The contraction of a protostar is halted eventually by:

a) the thermal energy generated by the contraction which **DECREASES** the gas pressure inside the protostar.
b) the thermal energy generated by the contraction which **INCREASES** the gas pressure inside the protostar.
c) the action of magnetic fields.
d) the action of the dynamo effect.
e) the heat generated by the turning on of nuclear burning which **INCREASES** the gas pressure inside the protostar.

SUGGESTED ANSWER: (e)

Wrong answers:
a) Adding heat and contraction together should increase gas pressure.
b) The thermal energy generated by contraction and the increasing density of the gas do increase pressure, but they do not stop the contraction.

Redaction: Jeffery, 2001jan01

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040 qmult 01000 1 4 1 easy deducto memory: H II region defined

Extra keywords: CK-307,321,322-3

12. Star formation in giant molecular clouds often results in the formation of OB associations: collections of hot, bright OB stars that ionize the surrounding molecular cloud and evaporate dust because of their strong ultraviolet emission. The gas region ionized by an OB associations is called a/an:

    a) H II region. b) small molecular cloud. c) a black hole. d) a dark cloud. e) He region.

    SUGGESTED ANSWER: (a)

    Wrong answers:

    b) As Lurch would say: "Aaaarh."

    Redaction: Jeffery, 2001jan01

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040 qmult 01500 1 4 3 easy deducto-memory: disk defined

Extra keywords: Sunlife

13. "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

    SUGGESTED ANSWER: (c)

    Wrong answers:

    a) Compact disks are disks, but not the right kind of disk.

    Redaction: Jeffery, 2001jan01

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040 qmult 01510 2 4 2 moderate deducto-memory: disk formation frequency

Extra keywords: CK-304, Sunlife

14. Disk formation is:

    a) a unique event that happen only in the case of the formation of the Sun.
    b) a common event in star formation as far as astronomers can tell.
    c) a process in nuclear burning.
    d) never observed in star formation.
    e) responsible for the heating up of the protostar.

    SUGGESTED ANSWER: (b)

    Wrong answers:

    d) It has been observed.

    Redaction: Jeffery, 2001jan01