Science Olympiad
Astronomy C
National Event - Michigan State University

May 25, 2024

Answer Key

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Section A (52 points)

1. (a) Cold Molecular Clouds (dark or absorption nebulas acceptable)
   (b) Photoionization (erosion due to high energy radiation)
   (c) Image 6
2. (a) Shock waves from X-ray outbursts
   (b) Image 1
3. (a) T Tauri, Herbig Ae/Be (accept Herbig)
   (b) F, Z
   (c) Core hydrogen to helium fusion stabilizes
4. (a) NGC 1333, Image 15
   (b) Herbig Haro, HH 7-11
   (c) Ionized jets of gas from the newly forming protostar collide with the clouds of gas and dust within the disk material
5. (a) Luhman 16 A/B (accept Luhman 16), Image 4
   (b) [1.5 pts] Luhman 16A has banded/striped clouds, Luhman 16B has patchy clouds, Image 11
   (c) R, M
   (d) 2M1207, Image 10
6. (a) TW Hya, Image 18
   (b) Image 22
   (c) Carbon monoxide, Image 2
7. (a) Disk instability – massive disk breaks into clumps which form protoplanets
   (b) AB Aur, Image 9
   (c) Image 23
   (d) HD 169142, Image 19
8. (a) [1.5 pts] Carbon & sulfur dioxide, Image 26
   (b) Image 21, emission spectroscopy or phase curves (accept either)
9. (a) Larger planets block more light and transit more frequently
   (b) HR 8799, Image 3
   (c) Beta Pictoris, Image 12
   (d) [1.5 pts] Main Sequence, H, B
10. (a) Image 24
    (b) Flares (also accept starspots or rotation)
11. (a) Debris disks are mostly dust, and protoplanetary disks are mostly gas (also accept optically thin vs. thick, respectively)
    (b) Continuous collisions of small bodies within the disk
    (c) [1.5 pts] Planets, asteroids, comets
12. (a) Trappist-1, P
    (b) Stellar wind (accept radiation)

13. (a) [2 pts] A is more luminous because the area under the curve is greater (and has a larger surface area). B is redder because it emits relatively less blue light than A. (0.5 pts for each correct answer and justification)

    (b) Visible, visible, infrared, infrared (0.5 pts for 2/4)

    (c) [1.5 pts] -0.79

    (d) [1.5 pts] K[0–3]V (0.5 pts for each part)

    (e) [1.5 pts] B–V because it captures the most variation in color index/SED "slope", whereas [3.6]–[4.5] doesn't change much. (0.5 pts for justification)

    (f) [1.5 pts] Reddening adds color excess which decreases the predicted temperature. For example, a hot star with reddening would look like a cool star without.

14. (a) O or B stars

    (b) Because O/B stars are short-lived, they end up ionizing the stellar nursery they formed in.

    (c) Reactants: A proton and an electron. Products: An (excited) neutral hydrogen atom and a photon. (0.5 pts for 2/4)

    (d) [1.5 pts] In recombination, the un-ionized hydrogen atom produced may be excited. The excited electron cascades down to the ground state and emit lower-energy photons, with the most dominant being the red H-alpha line.

    (e) [1.5 pts] D, because the rate of growth is highest at beginning and slows over time due to the inverse square law and the increase in recombination rate. (0.5 pts for justification)

Section B (15 points)

15. (a) [1 pt] GJ699
    (b) [1 pt] 2019-06-17
    (c) [1 pt] There is a single bright point source near the center of the JS9 window.
    (d) [1.5 pts] Primarily soft X-rays
    (e) [1.5 pts] $\sim 800\,\text{eV}$
    (f) [2 pts] $0.247\,\text{nm}$
    (g) [2 pts] They would not reach the Earth's surface (opacity at that wavelength is $\sim 100\,\%$).
    (h) [1.5 pts] 677155523 seconds
    (i) [1.5 pts] 11 counts
    (j) [2 pts] Severe flaring might prevent the star's planets from having a stable atmosphere; life on such a planet would be unlikely.

Section C (33 points)

16. (a) [1 pt] Energy (0.5 pts for momentum)
    (b) [1 pt] $v_A = 12.9\,\text{km/s}$, $v_P = 27.2\,\text{km/s}$
    (c) [2 pts] $t_{\text{transit}} \in [14.2, 30.0]\,\text{h}$ (or $[9.66, 12.9]\,\text{h}$)
    (d) [2 pts] $d_{\max} = 33.9\,\text{pc}$
17. (a) [2 pts] $T = \sqrt{\frac{4\pi^2 a^3}{GM}}$
    (b) [1.5 pts] $\sqrt{3}r$
    (c) [1.5 pts] $F = \frac{\sqrt{3}GM_\odot^2}{3r^2}$ pointing towards the barycenter
    (d) [2 pts] All of Kepler's laws apply here. Kepler's 2nd law is a consequence of the conservation of angular momentum, and thus it always applies. Star I's equation of motion is $\ddot{\vec{r}} = \frac{\sqrt{3}GM_\odot}{r^2}$. Therefore, it moves under an inverse square force law, and its motion is equivalent to that of a 2-body system. Hence, Kepler's 1st and 3rd laws also apply.
    (e) [1 pt] $2187\,\text{yr}$
    (f) [1 pt] $700\,\text{AU}$
    (g) [1 pt] $1\,G_{SC}$
    (h) [2 pts] $2.0 \times 10^{-6}\,G_{SC}$
    (i) [2 pts] $T_e = 255\,\text{K}$ (or $303\,\text{K}$)
    (j) [2 pts] $T_s = 288.3\,\text{K}$ (or $343\,\text{K}$), within the habitable zone
    (k) [1 pt] $0.607\,\text{AU}$
    (l) [1 pt] $8.14\,G_{SC}$
    (m) [2 pts] $T_e = 430.7\,\text{K}$ (or $381\,\text{K}$), not in the habitable zone
18. (a) [1 pt] $0.77''$
    (b) [1.5 pts] 0.32
    (c) [1.5 pts] 3.56
    (d) [1.5 pts] $0.0894\,\text{m/s}$
    (e) [1.5 pts] $1.96 \times 10^{-7}\,\text{nm}$