Macomb County Science Olympiad
2016
Astronomy Division C Exam

March 19, 2016

Team Number:_____ School Name: _____

Participant Names: _____

_____

INSTRUCTIONS:

1. In the exam packet there is an exam with 46 questions, two pages of images, scrap paper, and one two-page answer sheet. Please make sure that you have all the materials at the start of the exam.
2. At the end of this event please place all materials back into the folder except the answer sheet which will be turned in separately. Missing exam materials will result in immediate disqualification of the team in question.
3. Only answers provided on the answer page will be considered. Do not write outside the designated spaces for each answer. You may write in the exam booklet and on any scratch paper that has been provided inside the exam packet.
4. Print legibly. Answers that cannot be read will be marked incorrect.
5. Answers that are deemed offensive will result in a disqualification for that team.
6. Include school name, school team number, and names of the participants at the top of the answer sheet as well as on the title page.
7. Be prepared to display your wristband to the supervisor when asked. If you do not have a wristband, you may not participate.
8. Each question is worth one point except questions 33 and 34, where each is worth 3 points. The total amount of points possible for the exam is 50.
9. Make sure to use proper units in answering the questions. Numerical answers that are correct with incorrect units will be marked incorrect regardless of the accuracy of the number.
10. When the time is up, the time is up. Continuing to write after the time is up risks immediate disqualification.
11. If you finish early you may turn the exam in before the allotted time limit and leave. Remember once you turn the exam in and leave you may not re-enter the room to fix any portion of the exam.
12. You may use two laptop computers, however Internet access is forbidden and any team attempting to do so will be disqualified, or you may use two three ring binders. All materials must be inserted into rings. All materials not three hole punched and inserted into rings will not be permissible and will be confiscated and may result in team disqualification.
13. You may use a combination of one laptop and one three ring binder within the scope of the rules.

Data for Sun:
1 Mo = 2.0×10^{30} kg
1 Ro = 7.0×10^{5} km
I Lo = 3.8×10^{26} W
1 To = 5778.0 K

Other Useful information
1 parsec = 3.26 ly
1 $M_{Jupiter}$ = 1.89813×10^{27} kg
1 Au = 149,597,870,700.0 m
G = 6.673×10^{-11} $N(m/kg)^2$

$$V_{planet} = \sqrt{\frac{G M_{star}}{R}} \qquad M_{planet} = \frac{M_{star} V_{star}}{V_{planet}} \qquad T_{equ} = T_{star}(1-a)^4 \sqrt{\frac{r_{star}}{2R}}$$

$$\frac{P^2}{R^3} = \frac{4\pi^2}{G(M_A + M_B)} \qquad \lambda_{max_{nm}} = \frac{2.9 \times 10^6}{T_{star_{Kelvin}}}$$

*R is the distance between two objects

Part A: Images

Questions numbered 1- 24 refer to image page one. All objects shown are from the published list in section 3c of the Astronomy rules in the 2016 Science Olympiad Manual. When naming objects please use the given names in the list of the rules (unless otherwise noted) or they will be marked incorrect. Image letters are found above the corresponding image.

1. Which lettered image represents a celestial object found in the constellation Pegasus?
2. Which lettered image on the image page is a molecular cloud?
3. Which lettered image on the image page is an area that is only 1 million years old and is thought to be forming planets in its debris disk?
4. What is the name of the star central to the system found in image H?
5. What is the name of the system pictured in image A?
6. Which lettered image on the image page can be found in the constellation Carina?
7. What is the name of the object that the arrow is pointing to in image J?
8. Which lettered image on the image page depicts the first object to have a detailed weather system?
9. What is the name of the system shown in image F?
10. Which lettered image on the image page shows a celestial object with spectral types A and B that is between 2 Mo and 8 Mo?
11. Which lettered image on the image page depicts WASP-18b?
12. Which lettered image on the image page shows a celestial object that is in a pre-main sequence stage similar to that of what the Sun probably passed through 4.5 billion years ago?
13. What is the name of the celestial object found in image C?
14. Which lettered image on the image page shows a system with a gamma doradus variable?
15. Which lettered image on the image page shows a FU Orionis star?
16. Which lettered image on the image page is the closest star forming region to the Earth?
17. Which lettered image on the image page contains a planet named Galileo?
18. What type of object is depicted in image G on the image page?
19. What type of star is shown in image L on the image page?
20. Which of the lettered images on the image page shows a T Tauri star?
21. What type of star is shown in letter I on the image page?
22. Which lettered image on the image page is a special case of a T Tauri star with mass transfer from a disk onto the T Tauri star to create large eruptions?
23. Which lettered image on the image page is a binary system consisting of a G type star and a red dwarf?
24. Which lettered image on the image page shows a system with a hot Jupiter?

Part B: H-R Diagram

For questions 25-30 please refer to the H-R diagram (image N) found on the second image page. Questions 31 and 32 are just general H-R diagram questions and do not refer to any letter on image N.

25. Which letter on the H-R diagram shows the closest position likely for brown dwarfs?
26. Which letter on the H-R diagram shows the most likely position for the parent star of GD 165?
27. Which letter on the H-R diagram shows the closest position likely for a T Tauri Star?
28. Which letter on the H-R diagram shows the closest position likely for a Herbig Ae/Be Star?
29. Which letter on the H-R diagram shows the closest position likely for a FU Orionis Star?
30. Which letter on the H-R diagram would represent the most likely place that a blue supergiant would be found?
31. What is the name of the branch on the H-R diagram that HR 8799 would be found on?
32. What is the name of the path on the H-R diagram taken by protostars on their way to the Main Sequence?

Part C: Calculations

Questions 33 and 34 have three parts a), b), and c) with each part worth one point. Therefore, questions 33 and 34 are a total of 3 points each. Please make sure to use the correct units when reporting each numerical answer and please report each value to three significant digits. At the bottom of the instructions page of this exam you may find some helpful formulas and constants.

33. Image M shows the radial velocity curve of host Star A, around which Planet B orbits. Star A has the same mass, radius, and luminosity as the Sun. Assume that the system has no inclination and Planet B has 0 eccentricity (a circular orbit). Using this information answer a), b), and c) below:
    a) What is the distance from Star A to Planet B, in AU, assuming Planet B has a mass much, much less than that of Star A?
    b) What is the velocity of Planet B in its orbit around Star A, in km/s?
    c) What is the mass of Planet B, in Jupiter masses?

34. Star D is found to have a parallax of 0.2", a radius = 0.600 Solar Radii, and a peak wavelength intensity of λ_{max} = 487.0 nm. A planet with the same mass and radius as the Earth orbits this star at a distance of 0.42 AU. Using this information answer a), b), and c) below:
    a) What is the distance in parsecs to Star D?
    b) What is the temperature of Star D, in Kelvin?
    c) What is the equilibrium temperature of the planet in Kelvin, given an albedo of 0.0?

Part D: Miscellaneous

Questions 35 – 46 pertain to general miscellaneous questions relating to objects given in section 3a, b, or c of the published 2016 Science Olympiad rules. Some questions are fill in the blank and some are multiple choice. All are one point each.

35. Planet formation can occur in the circumstellar disk of a forming star. In this disk gases condense to turn into small solid objects. After condensation these small solid objects stick together through a weak electrostatic force. What is this process called?

    a) Protoplanet b) Accretion c) Compression d) Sticky Force

36. What types of objects are created as the direct result of the process described above?

    a) Protoplanets b) Protostars c) Planets d) Planetesimals

37. Which one of the exoplanets below is found in the habitable zone for its parent star?

    a) 51 Pegasi b b) WASP 43b c) Kepler 186f d) HR 8799

38. Which one of the objects below is a brown dwarf?

    a) 51 Pegasi b b) WISE 0855-0714 c) HAT-P-11b d)HD 106906b

39. Which of the following classifications of pre-main sequence stars has the highest mass?

    a) T Tauri b) FU Orionis c) Herbig Ae/Be d) None of these.

40. Which of the following classifications of pre-main sequence stars has the lowest mass?

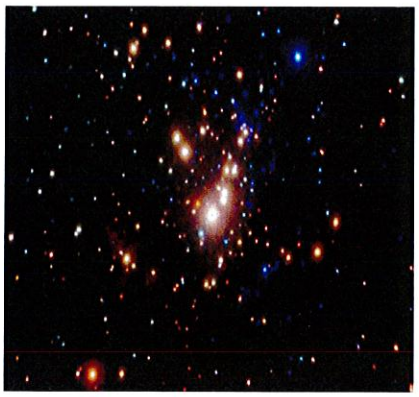
    a) T Tauri b) FU Orionis c) Herbig Ae/Be d) None of these.

41. Which two spectral types of stars cause HII regions to glow?

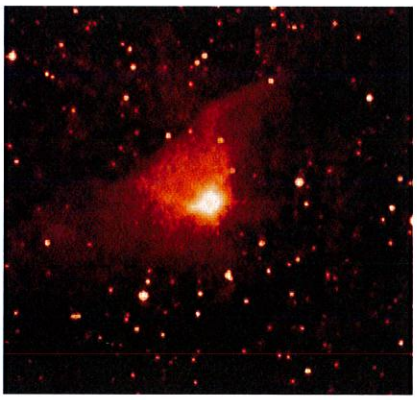
    a) A & F b) G & M c) M & A d) O & B

42. Name one physical quantity needed to apply the radial velocity method of exoplanet detection other than velocity?
43. Why are Brown Dwarfs not on the Main Sequence?
44. What method was used to detect the planets in the HR 8799 system?
45. WASP 43b is classified as what type of exoplanet?
46. How can an observer obtain the effective temperature of a planet via the transit method?

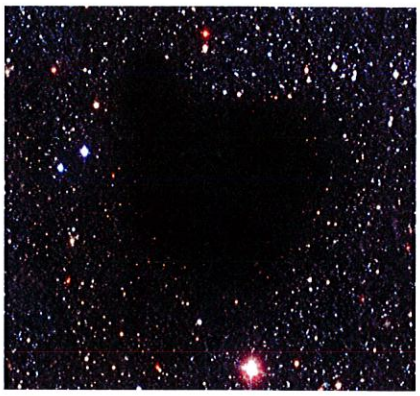
A



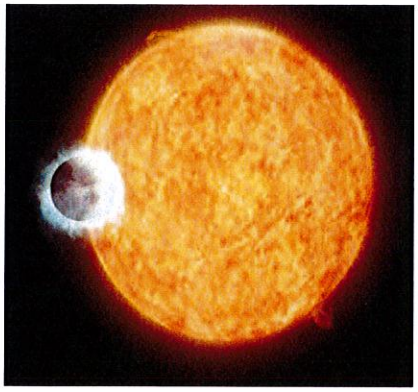
B



C

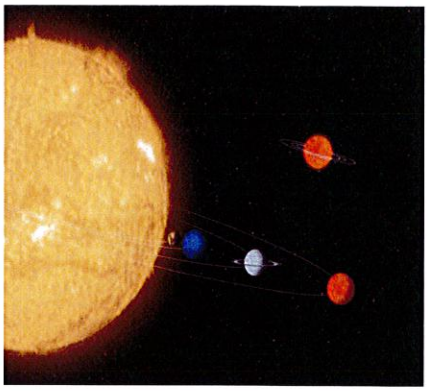


D

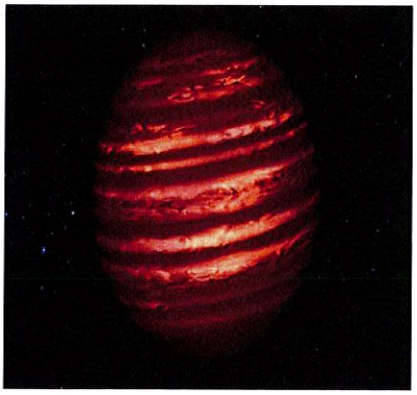


E

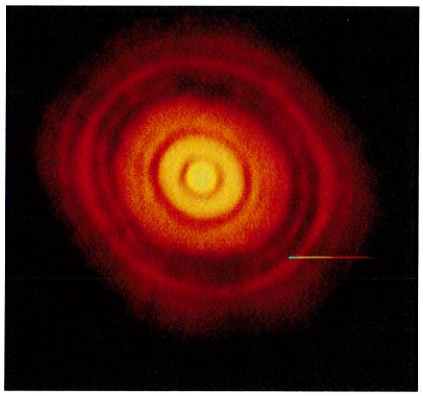
F



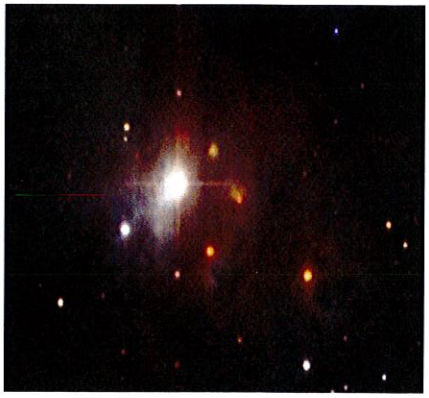
G



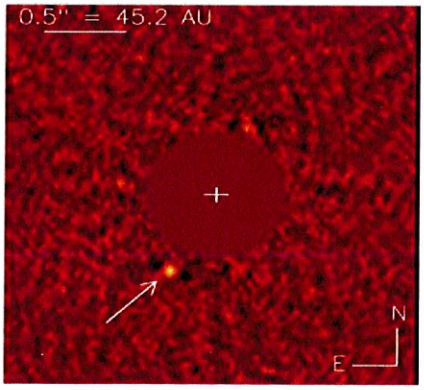
H



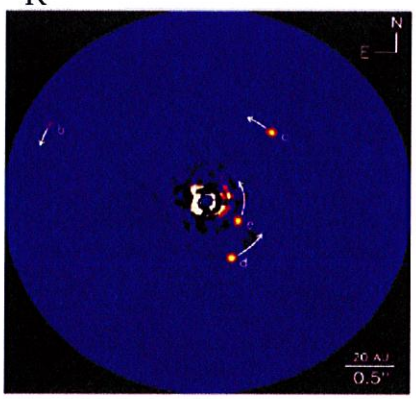
I



J



K



L

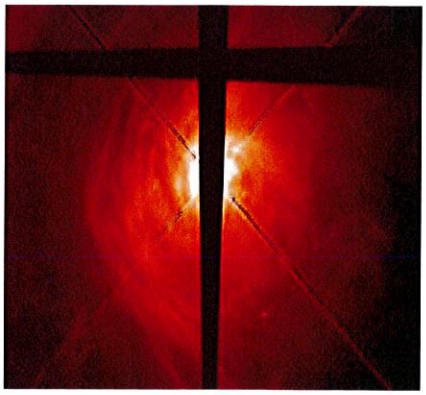


Image M

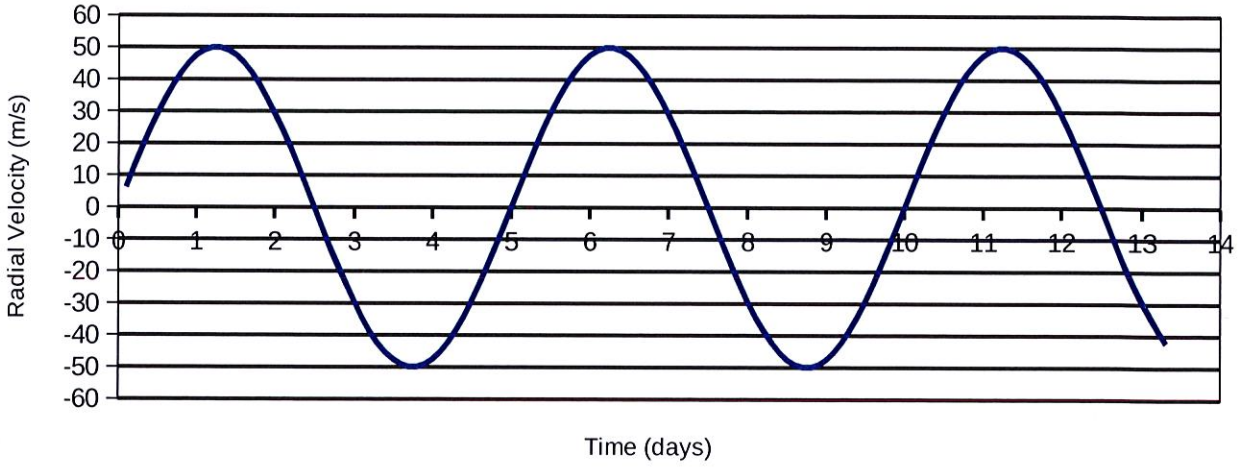
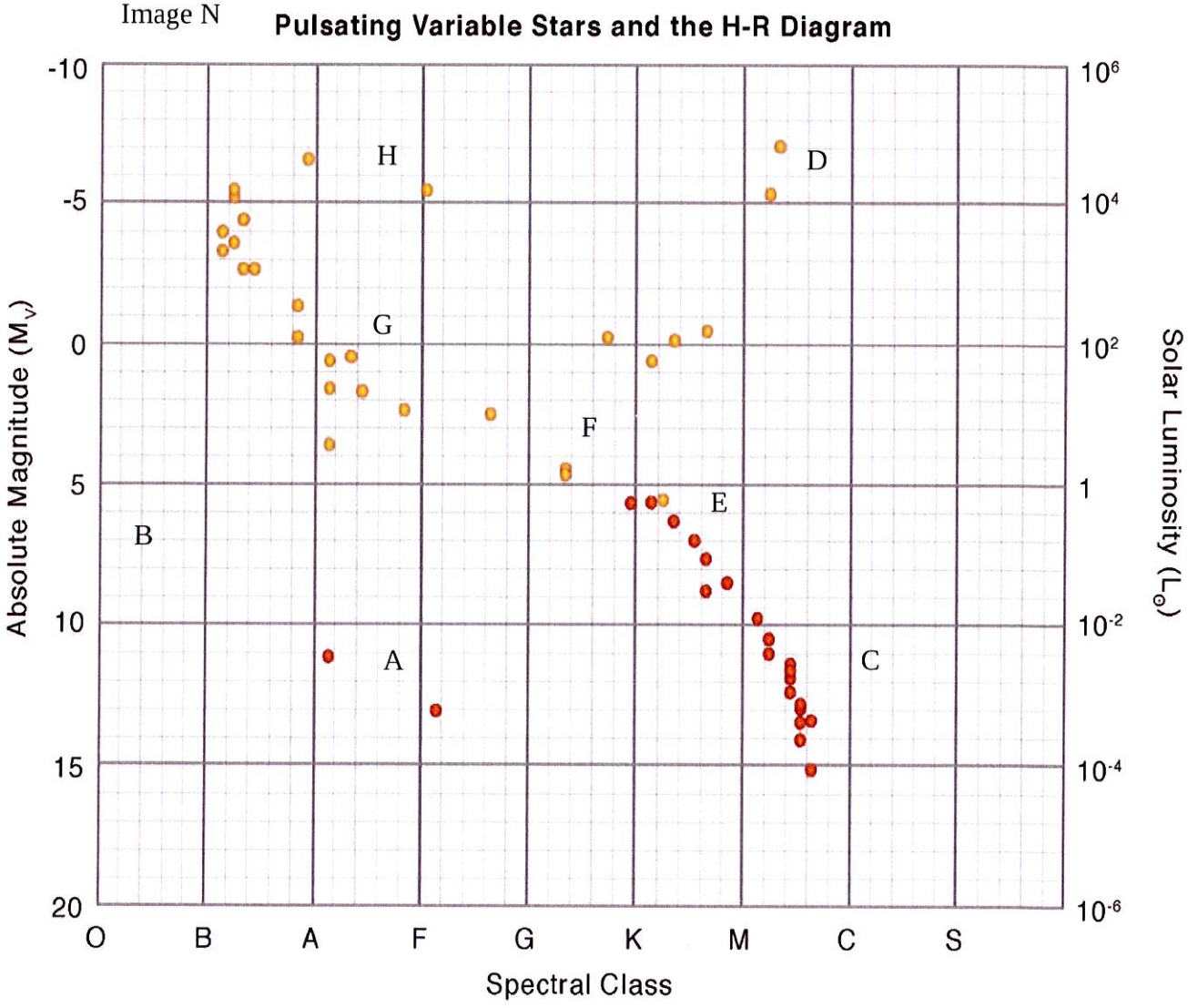


Image N



Astronomy Exam Division C Answer Sheet Team Number _____ School Name Key

Participant names: _____

1. K
2. C
3. H
4. HL Tauri
5. M 42
6. J
7. HD 95086
8. G
9. 55 Cancri
10. I (T1)
11. D
12. E
13. Barnard 68
14. K
15. B
16. A
17. F (T7)
18. Brown Dwarf
19. AB Aurigae
20. E
21. Herbig Ae/Be
22. B
23. F
24. D (T2)
25. C (T8
26. A
27. E (T4)
28. G
29. F
30. H

Astronomy Exam Division C Answer Sheet Team Number _____ School Name Key (cont.)

Participant names: _____

31. Main Sequence

32. Hayashi Track or Birth line

33. a) 5.73×10^{-2} AU
    b) 125 km/s
    c) 0.421 Jup

34. a) 5.00 pc
    b) 5.95×10^{3} K
    c) 344 K

35. B

36. D

37. C

38. B (T5)

39. C

40. A

41. D

42. Wavelength or Speed of light

43. They are not massive enough to fuse hydrogen.

44. Direct Imaging

45. Hot Jupiter (T6)

46. By looking at the depth of the Secondary Eclipse.