MIT Science Olympiad Invitational

January 24th, 2015

Astronomy

Team Name: _____

Team Number: _____

Team Members: _____

_____

Questions 1 – 34 are related to Image Sheet 1

1. Which location in Image A corresponds to a Sun-like star?
2. Which location in Image A corresponds to a Red Giant star?
3. Which location in Image A corresponds to a star in its final stage of evolution?
4. Which location in Image A corresponds to a star with the largest radius?
5. Which location in Image A is along the path of formation for a solar-mass star?
6. Which location in Image A is along the path of formation for a 10 solar-mass star?
7. Which location in Image A corresponds to a T-Tauri type star?
8. Which location in Image A corresponds to a main-sequence star that will become a Supernova?
9. Which location in Image A corresponds to a main-sequence star that will become a planetary nebula?
10. Which location in Image A corresponds to a star that will stay on the main-sequence for more than 15 billion years?
11. A star at location ii in Image A has an Apparent Magnitude of +10, what is the distance (in parsecs) to that star?
12. How many times more luminous than the Sun is a star at location v in Image A?
13. Starting from a molecular cloud, describe the process formation process for a one solar mass star with a stable system of planets.

14. Which location in Image A corresponds to a main sequence star with Spectrum xi in Image B?
15. Which Spectrum in Image B corresponds to a star with a spectral class of K?
16. Which Spectrum in Image B corresponds to he hottest star?
17. Which Spectrum in Image B corresponds to the coolest star?
18. What is the surface temperature of a main sequence star with Spectrum viii?
19. A star with Spectrum ix in Image B is on the main-sequence and is at a distance of 10 pcs. What is the apparent magnitude of this star?
20. What portions of the electromagnetic spectrum is represented in Image C?
21. Which Line in Image D corresponds to Line xii in Image C?
22. Which Element corresponds to Line xv in Image D?
23. Describe the relative strengths of Hydrogen lines in the spectra of O, A, and G type stars. Explain the physical cause of those relative strengths.

24. Which Curve in Figure E corresponds to the hottest stellar surface temperature?
25. What is the surface temperature (in K) of a star that corresponds to Curve xvii Figure E?
26. If a star corresponding to Curve xvii in Figure E were on the main sequence, at which Position in Figure A would it be plotted?
27. If a star corresponding to Curve xix in Figure E has a luminosity of 1,000 solar luminosities, what is the radius of that star (in solar radii)?
28. If a star corresponding to Curve xvii and a star corresponding to Curve xix in Figure E have the same absolute magnitude, how many times larger must the radius of the star corresponding to Curve xix be than the radius of the star corresponding to Curve xvii?

29. A star is measured to have a parallax of 1.0 arc seconds, what is the distance (in parsecs) to that Star?
30. If one of the measurements of that star (from question 29) was made at location xx in Image F. At which location in Image F would the apparent position of the star change by 1.0 arc second?
31. If the apparent position of the star (from question 29) was also measured at location xxi in Image F, how much would the apparent position of the star change (relative to the measurement at location xx) (in arc seconds)?
32. If an instrument at position xxiv in Figure G measures the energy flux from the Sun and an identical instrument measures the energy from the Sun at Position xxv. How many times higher will the measurement at position xxiv be?
33. The instrument (from question 32) measures the energy flux from Aldebaran. How many times higher will the measurement at Position xxv be than at Position xxiv?
34. Assume that a mission is planned for a spacecraft with a highly eccentric orbit around the sun. One of the science objectives for this spacecraft is to create a catalog of stellar distances for nearby main sequence stars. One proposed method for achieving this objective is geometric parallax the other proposed method is spectroscopic parallax. Describe how each method could be implemented. Then describe potential sources of error for each method. Finally, given the high eccentricity of the orbit, defend which method you think would produce a more uniformly accurate distance catalog.

Questions 35 – 67 are related to Image Sheet 2

35. Image Q shows a DSO located in which constellation?
36. The bright object on the left side of Image Q is actually a variable star. What kind of variable star is it?
37. Approximately how far apart, in AU, are the two bright objects in Image Q?
38. In 2009, another object was detected that orbits inside the orbit of the boxed object in Image Q. This object, a cool gaseous giant, is classified in which group of exoplanets?

39. Which image shows the DSO that contains the youngest known stars outside the Milky Way?
40. What structure is this object a smaller part of?
41. What galaxy is this object a part of?

42. Which image shows an object which is a member of the Castor Moving Group along with the DSO shown in Image S?
43. The powerful auroral emissions shown in Image S are consequences of what physical process characteristic of the object?

44. Which Image shows DSO HR8799?

45. What are the two most common designations for the object shown in Image L?
46. Given that this system is comprised of two brown dwarfs and one sub-brown dwarf mass companion, what is the maximum mass of this system in solar masses (to 2 significant digits)?

47. Which Image shows TW Hya?
48. In 2011, astronomers announced that this object contained an abundance of cool water in a planet-forming ring around the star. Ice formation is indicated in this disk by signatures of what two isomers of water?

49. Which image shows the same object as is pictured in Image R?
50. This object, compared to other objects of the same type, shows an excess of emission in what portion of the electromagnetic spectrum?
51. This object is thought to be a source of what objects in our own solar system?

52. Image W shows which DSO?
53. Which sub-image, (1, 2, or 3) shows the image of the object taken using the Atacama Large Millimeter array?

54. Which image shows an exoplanet which is hypothesized to have such extreme surface conditions as 7000 km/hr glass rains, a 260 K temperature change between day and night temperatures, and an atmosphere high in methane?
55. This planet is actually being evaporated by its host star at a rate of 1-100 gigagrams per second! Which other image shows a DSO in which the exoplanet is being rapidly evaporated by its host star?

56. Image J shows DSO CoRoT-2. In what region of the electromagnetic spectrum was this image taken?
57. Abundance of what element in this spectral analysis of this system confirms that it is still very young?

58. Which exoplanet is shown in Image Y?
59. The exoplanet in shown in Image Y is noteworthy for its
    A. high volume, high density
    B. high volume, low density
    C. low volume, high density
    D. low volume, low density
60. What substance do atmospheric studies suggest could be found on the exoplanet as vapor, liquid, superfluid, high-pressure ice, or plasma due to the atmosphere's wide range of temperatures and pressures?

61. Write the 3 most common designations of the object shown in Image K.

62. Which image depicts the surface of Kepler-7b, an exoplanet with hemispheric cloud systems mapped using over 3 years of data from the Kepler Mission?

63. Which DSO is also known by the catalogue name TWA 27?
64. Which image shows this DSO?
65. This DSO is thought to be part of the star association of the DSO shown in which image?

66. Which image shows the prototype star of a class of variables representing a transient phase the T-Tauri stage of a young star?

67. What is the unofficial name for the exoplanet shown in Image P?

Questions 68 – 100 are related to Image Sheet 3

68. It is thought that deuterium burning may occur in the core of Gliese 229b and/or its companions. Based on the reaction shown in Image AL, what mass of deuterium, in kilograms, would be required to support a luminosity 100,000 times dimmer than the sun for 1 GYr?
    Mass of proton: 1.6726×10^{-27} kg
    Mass of neutron**:** 1.6749×10^{-27} kg
69. Despite the fact that only 2 objects primarily influence the light curve of WISE 1049-5319, it shows distinct luminosity variations due to varied surface illumination and atmospheric conditions. Which light curve shows these variations?
70. The dynamic atmosphere of brown dwarf component Luhman 16 is predicated to have 10 circulatory bands of weather by what relation, which factors in characteristics such as Coriolis force, temperature, and turbulence?

71. Image AA shows a violent outburst characteristic of what young stellar variable stars?
72. Which image shows the prototype star of this class of variables?
73. Many stars of this type have similar spectral type at peak magnitude, associated characteristic coma-shaped nebulas, and broad heavily shifted spectral lines. What is the name for this spectral profile, indicative of dynamic mass loss?
74. This star has a peak wavelength of 2000 nm. If this peak is observed at 2030 nm, is matter moving towards or away from the observer?
75. How fast is this matter moving?

76. Image AJ shows the transit of which exoplanet in front of its host star?
77. Because the period of this exoplanet has been measured to such precision, which fundamental physical principle can it be used to confirm?
78. Given that this exoplanet has a mass of about 0.69 M_J and a radius of about 1.35 R_J, find the ratio between the density of this exoplanet and the density of Jupiter.
79. 2M1207 contains the first extrasolar planetary-mass companion for which what was accomplished?
80. The distance to this object, originally though to be about 70 parsecs, was refined to 53 parsecs in 2005 using what method?
81. Due to the high mass of the exoplanet in this system, what category name has been coined for these extremely high mass companions nearly able to achieve deuterium fusion?

82. Given that HR8799b has a semimajor axis of 68 AU and a period of 460 years, what is the mass of HR8799?
83. Which image shows the hypothetical light curve of a multiple-transit system like HR8799?

84. Which image shows the spectrum associated with GJ1214b?
85. This exoplanet's host star exhibits extrinsic variability at intervals of 53 days. What is this variability due to?
86. GJ1214b is among the coldest known solar system exoplanets. Given that it has a radius of 2.678 R_E and a temperature of about 475 K, what is the luminosity of GJ1214b?

87. Which image shows the transiting light curve of HD189733b?
88. Given that HD189733 has a mass of 0.846 M⊙ and radius 0.781 R⊙ and HD189733b has an orbital radius of 0.031 AU, what is the length of transit in hours? (assume an inclination of 0˚ and neglect the radius and mass of the exoplanet)

89. The first ever X-ray flare associated with a brown dwarf is associated with which DSO?
90. Which image on Image Sheet 3 shows this outburst?

91. Some studies indicate that the HII region of M20 is best characterized by a two temperature model, including regions of 20 K gas and regions of 2000K gas. What is the peak wavelength of each of these temperature emissions?
92. In what two regions of the electromagnetic spectrum would you expect to find these peaks?

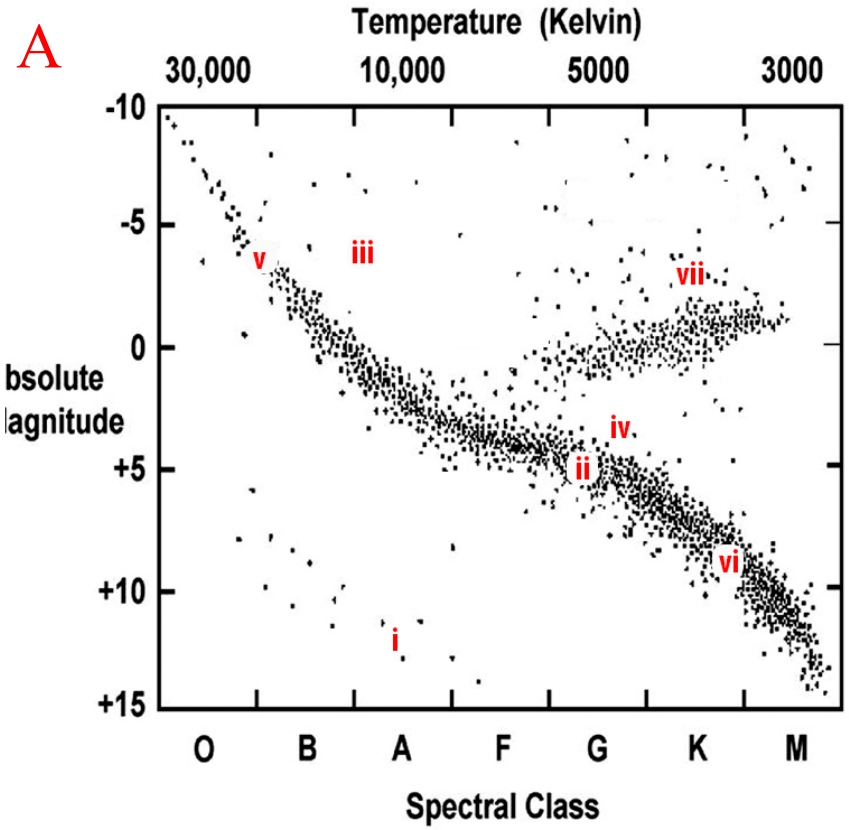
Kepler-7 is nearing the end of its life on the main sequence with a mass of 1.35 M⊙, a radius of 1.84 R⊙, and a temperature of 5933 K.
93. Which image shows the light curve of Kepler-7b?
94. Find the luminosity of the Kepler-7 using the mass-luminosity relationship.
95. Find the luminosity of the Kepler-7 using the Stefan-Boltzmann law.
96. Why do these luminosity values differ? Which is likely to be more accurate in this case? Why?
97. Despite how diffuse it is, Kepler-7b has an albedo comparable to that of the Earth (0.3). Given that Kepler-7b has a radius of 1.478 R_J and orbits 0.06 AU from its host star, find the rate at which Kepler-7b absorbs energy in the form of stellar flux.

98. Which image shows the light curve of CoRoT-2?

99. Which Image shows the light curve of a Classical T-Tauri Star?
100. TW Hya is a CTTS. What characteristic do CTTS's have that WTTS's do not?

IMAGE SHEET 1

A



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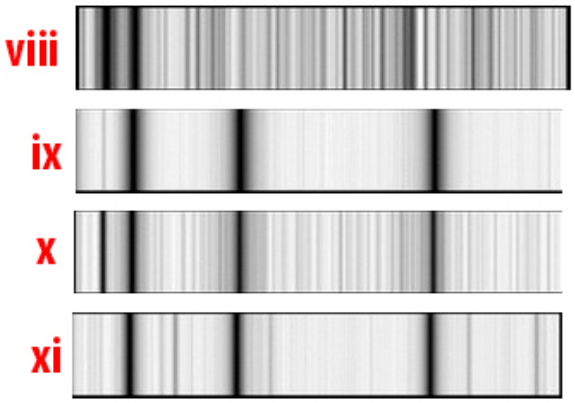

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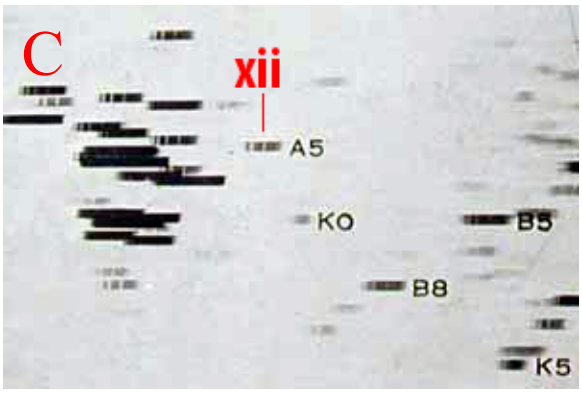

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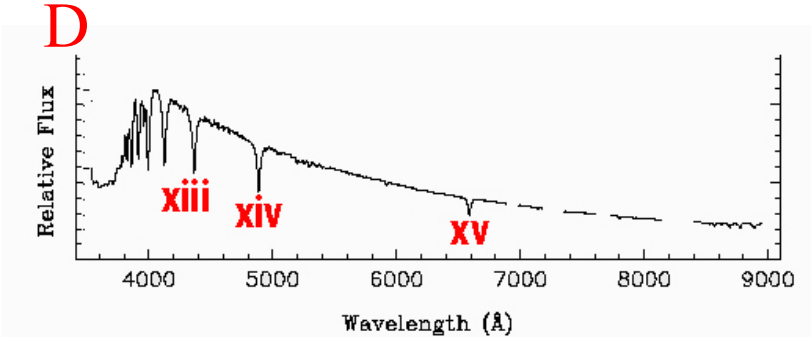

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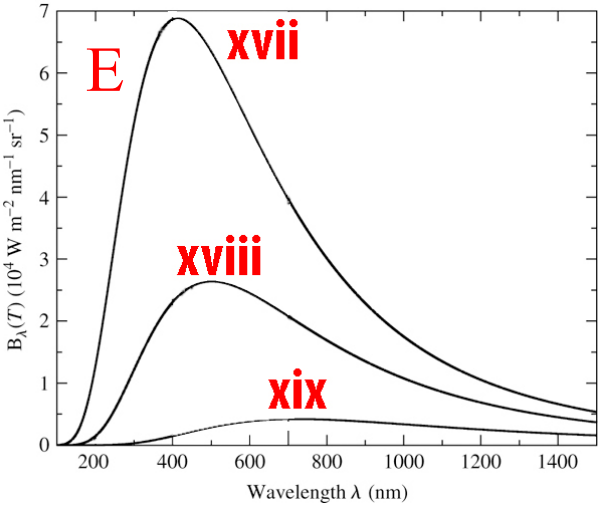

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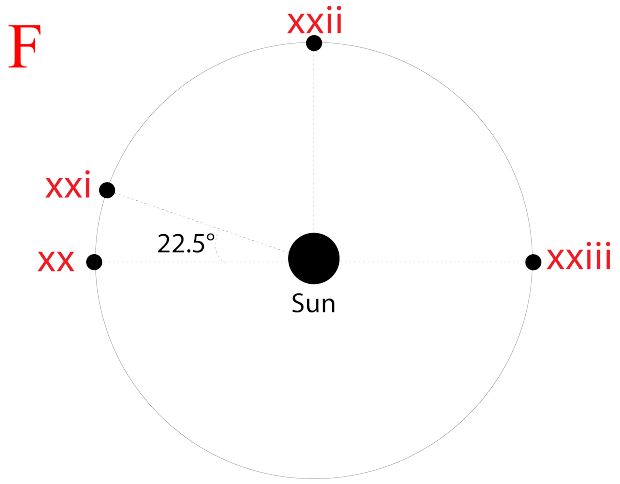

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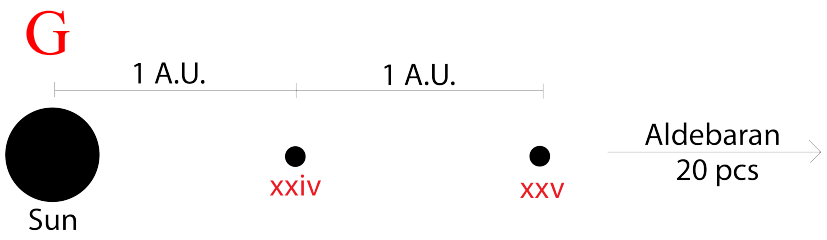
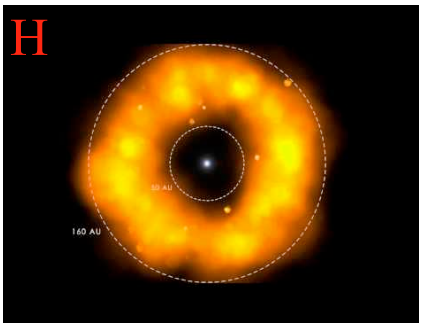


IMAGE SHEET 2

H



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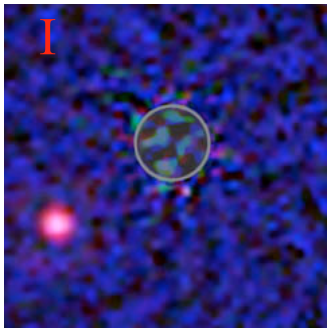

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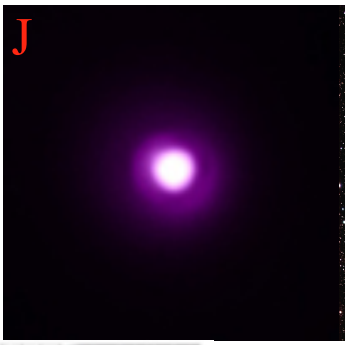

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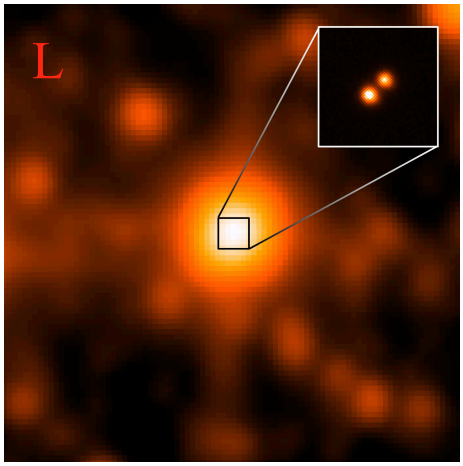

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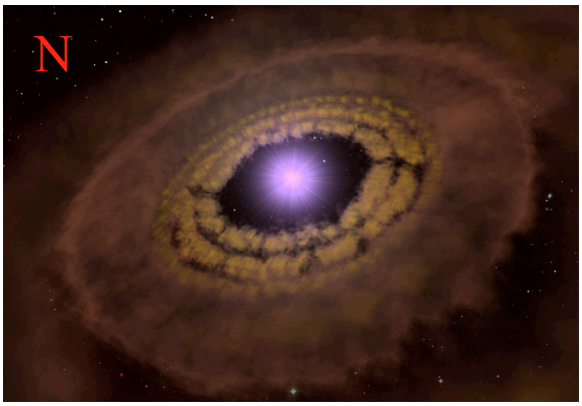

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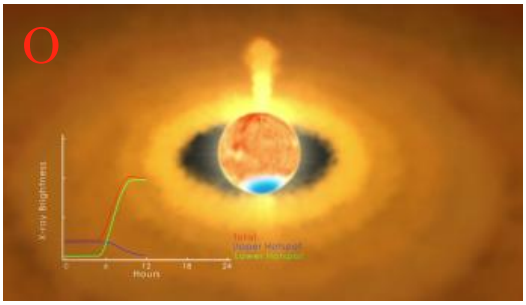

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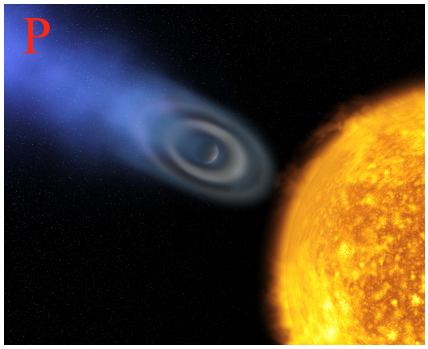

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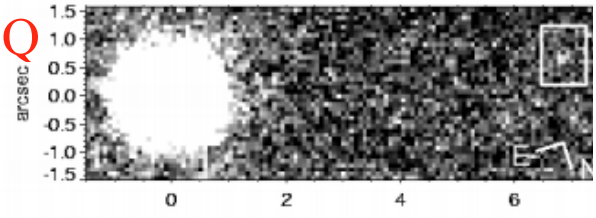

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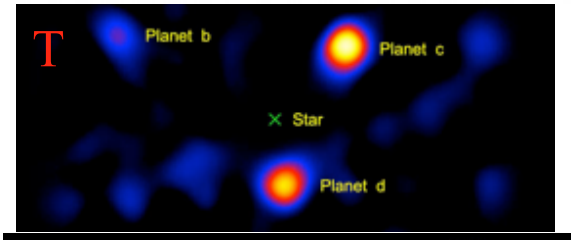

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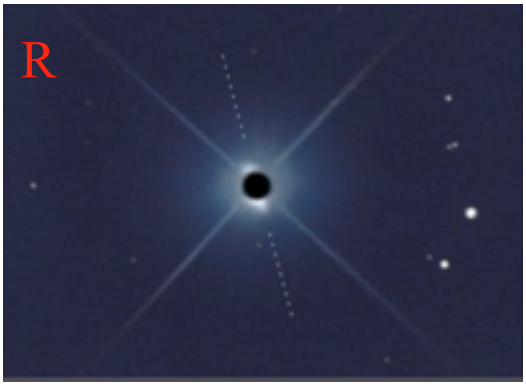

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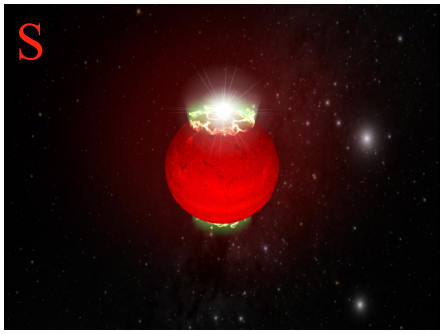

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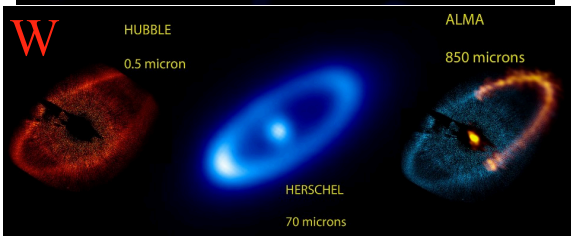

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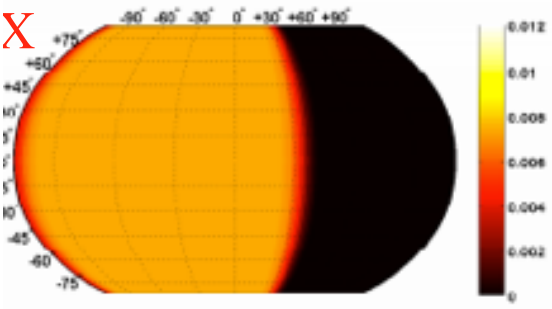

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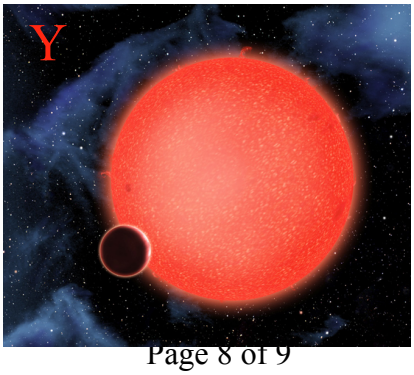

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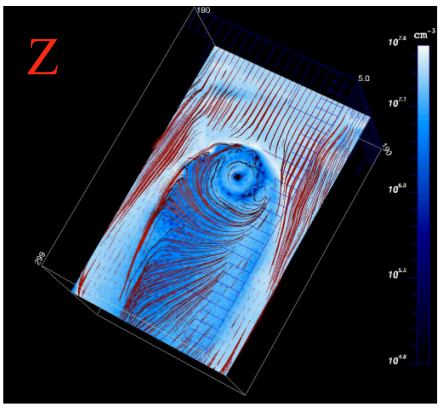

IMAGE SHEET 3

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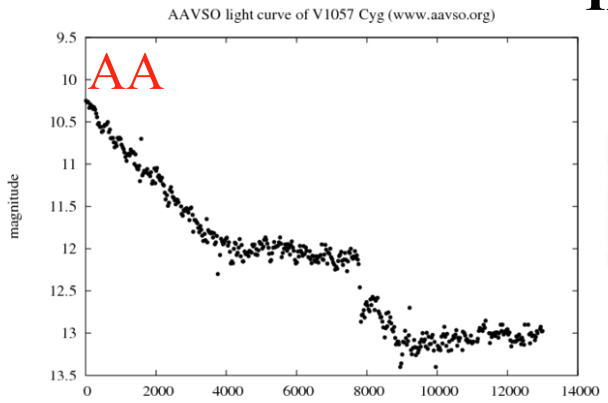

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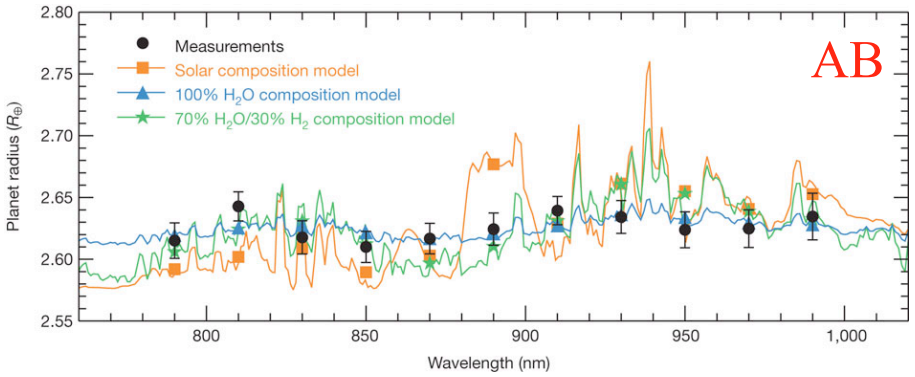

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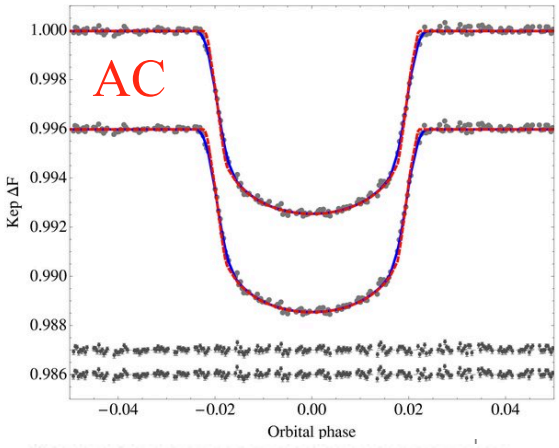

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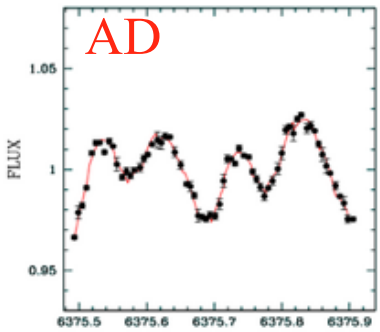

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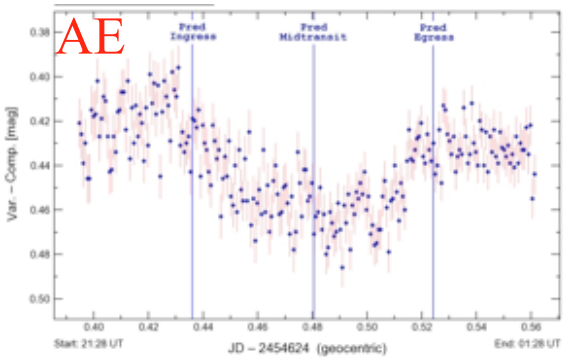

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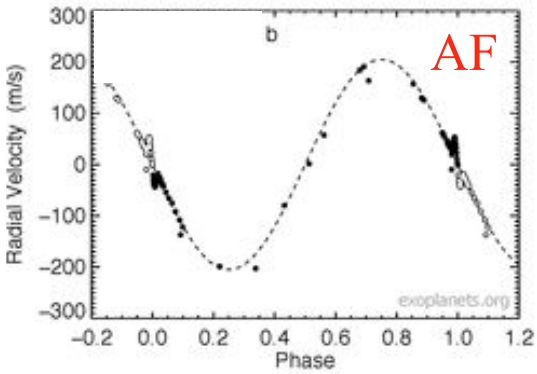

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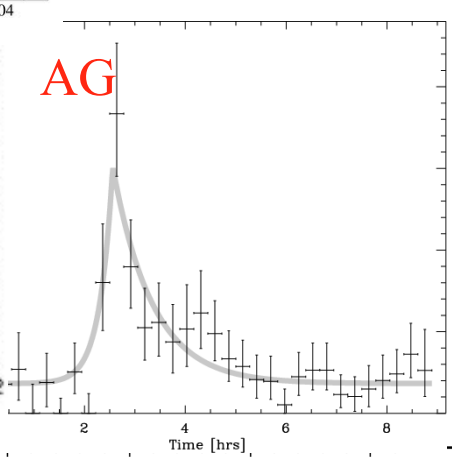

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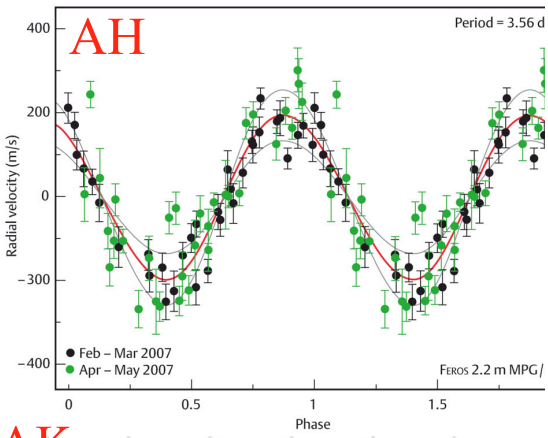

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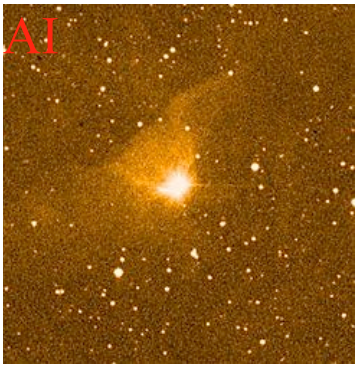

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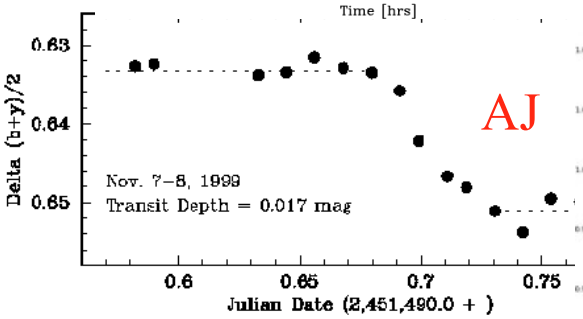

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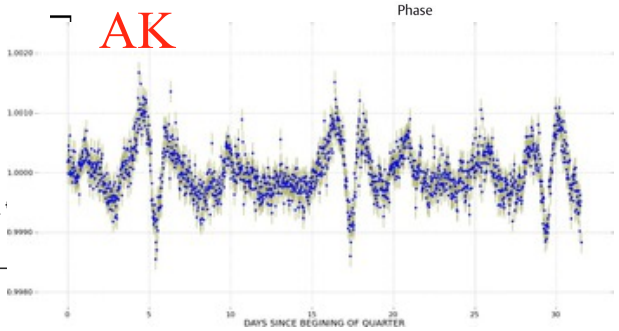

AL

$$ {}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n + 3.27\,MeV $$