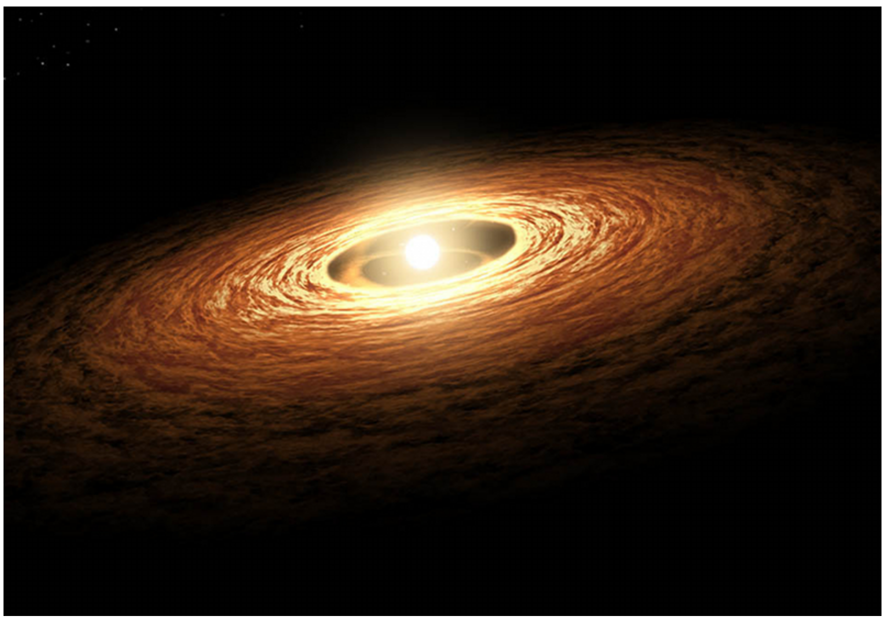
Score: 69 / 69

Astronomy Tryout Test

Written by: WW-P HS South



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School: WW-P HS South ______________ Number: ______________

Instructions: This test consists of three sections: a multiple-choice general knowledge section, a short-answer DSO section (with images), and a open-ended calculations section. The questions in each section generally increase in difficulty and cover a wide range of difficulties. The test is worth 69 points. Kudos to anyone who can get a score of 42 or more.

Remember to refer to the **image sheet** for section 2.

Section 1: General Knowledge

Instructions: There are 20 questions worth 1 point each. Select the one correct/best answer for each question.

1. Stars usually form from the collapse of what astronomical objects?
   (a) Globular clusters
   (b) Open clusters
   (c) Molecular clouds
   (d) Coronal gas

2. In what year was the Kepler spacecraft launched?
   (a) 2008
   (b) 2009
   (c) 2010
   (d) 2011

3. In which of the following objects would a T Tauri star most likely be found?
   (a) Open cluster
   (b) Molecular cloud
   (c) Globular cluster
   (d) Supernova remnant

4. Currently, the most successful method of detecting extrasolar planets is:
   (a) Radial velocity
   (b) Transit
   (c) Direct Imaging
   (d) Microlensing

5. Low-mass brown dwarfs and high-mass planets differ mainly in their:
   (a) Mass
   (b) Size
   (c) Temperature
   (d) Location

6. While star formation often occurs in diffuse nebulae, it rarely does so in emission nebulae. Why?
   (a) Gas and dust in emission nebulae is blown away by bright stars in the region
   (b) The temperature is too hot for gas and dust to condense
   (c) Supernovae do not occur in emission nebulae, as the stars there are young
   (d) Emission nebulae do not contain enough matter for star formation

7. Measuring the transit spectra of stars and planets yields the most data regarding a planet's atmospheric composition. During what part of what transit is the most useful?
   (a) Star in front, planet completely obscured
   (b) Star in front, planet partially obscured
   (c) Planet in front, planet completely in front of star
   (d) Planet in front, planet partially in front of star

8. During the formation of the planets, the orbits of the inner planets generally moved:
   (a) Inward, since the disk surrounding the Sun rotated slower than the planets did
   (b) Inward, since the disk surrounding the Sun rotated faster than the planets did
   (c) Outward, since the disk surrounding the Sun rotated slower than the planets did
   (d) Outward, since the disk surrounding the Sun rotated faster than the planets did

9. The presence of what element distinguishes high-mass brown dwarfs from low-mass stars?
   (a) Hydrogen
   (b) Helium
   (c) Lithium
   (d) Berylium

10. The light curve of a FU Orionis star is characterized by:
   (a) Sinusoidal shape
   (b) Spikes
   (c) Plateaus
   (d) Irregular erratic variation

11. Which of the following telescopes do not observe in the sub-mm wavelength?
   (a) James Clerk Maxwell Telescope
   (b) Herschel Space Observatory
   (c) Filin Telescope
   (d) Heinrich Hertz Telescope

12. The limb darkening effect observed in transits is most prominent in:
   (a) Shorter wavelengths
   (b) Longer wavelengths
   (c) Extreme wavelengths (short and long)
   (d) Moderate wavelengths

13. FU Orionis stars are believedd to be related to T Tauri stars because:
   (a) FU Orionis stars are T Tauri stars that form a large accretion disk
   (b) FU Orionis stars are T Tauri stars that are generating Herbig-Haro objects
   (c) FU Orionis stars are T Tauri stars that have experienced a sudden mass transfer
   (d) FU Orionis stars are T Tauri stars that do not exibit polar jets

14. Which of the following is not true regarding the radial velocity method, through measuring Dopplar shift, of extrasolar protoplanet detection?
   (a) This technique is independent of distance, so it is often used to find planets around stars thousands of light-years away
   (b) This technique is more effective when stars are rotating slower, so planets around large stars can be detected if the star is highly evolved
   (c) This technique is more effective when the planet-star ratio is higher, so large planets around small stars are the most commonly detected
   (d) This technique can measure the eccentricity of a planet's orbit, but it can only find a lower bound on the mass of the planet

15. Herbig-Haro objects exhibit prominent emission lines in all but which element?
   (a) Hydrogen
   (b) Helium
   (c) Oxygen
   (d) Sulfur

16. Exozodiacal dust is usually:
   (a) Less than 10 AU from the star and warm
   (b) Less than 10 AU from the star but cold
   (c) More than 10 AU from the star but warm
   (d) More than 10 AU from the star and cold

17. Which of the following is not true regarding Herbig Ae/Be stars?
   (a) They are more massive analogs to T Tauri stars
   (b) They contain Balmer emission lines in their spectrum
   (c) They must be spectral type F0 or earlier
   (d) They have infrared radiation excess due to free-free emission

18. The nebular hypothesis is the most widely accepted model of the formation of our Solar System. An alternate hypothesis, however, was proposed, due to traces of Iron-60 decay in meteorites. This hypothesis says that:
   (a) The Sun formed from the merging of two small red dwarfs
   (b) The Sun formed in the midst of a highly active region with large stars
   (c) The Sun formed as a binary system, but the second star was lost
   (d) The Sun formed due to the interaction of two globular clusters

19. A bright star has just formed in a molecular cloud and created a H-II region. The regions, from closest to farthest from the star, are most likely:
   (a) H-II region, shock wave, disturbed H-I region, ionization front, undisturbed H-I region
   (b) H-II region, ionization front, disturbed H-I region, shock wave, undisturbed H-I region
   (c) Disturbed H-II region, shock wave, undisturbed H-II region, ionization front, H-I region
   (d) Disturbed H-II region, ionization front, undisturbed H-II region, shock wave, H-I region

20. Star A and star B are T Tauri stars found to have the same luminosity. It is also determined that both stars are generally increasing in luminosity. Star A has a mass of 0.7 solar masses and a radius three times that of star B. What is the approximate mass, in solar masses, of star B?
   (a) 0.65 $M_\odot$
   (b) 0.69 $M_\odot$
   (c) 0.73 $M_\odot$
   (d) 0.77 $M_\odot$

Section 2: Deep Sky Objects

Instructions: There are 12 short answer questions. Refer to the **image sheet** for this section. This section is worth 25 points.

21. Consider the Trifid Nebula: [1]
    (a) What image shows this DSO? [0.5]
    Image 4
    (b) In what constellation is this DSO? [0.5]
    Sagittarius
22. Consider the star FU Orionis: [2]
    (a) Which image shows FU Orionis? [0.5]
    Image 7
    (b) Is FU Orionis a dwarf, subgiant, giant, bright giant, or supergiant? [0.5]
    Supergiant
    (c) Describe light curve of FU Orionis from 1937 - 1947. [1]
    The light curve gradually increased from the 16th magnitude to the 9th magnitude over the course of 1937, then stayed at that brightness.
23. Consider HR 8799: [1]
    (a) How many known planets orbit this DSO? [0.5]
    4
    (b) Compared to most stars, HR 8799's surface nickel content is: [0.5]
    Less
24. Consider the DSO closest to the Earth: [2]
    (a) What image shows this DSO? [0.5]
    Image 5
    (b) Who discovered this DSO? [0.5]
    Kevin Luhman
    (c) In what constellation is this DSO? [0.5]
    Vela
    (d) What is the period, to the nearest 5 years, of this DSO? [0.5]
    25 years
25. Consider the star CoRoT-2: [2]
    (a) What is the spectral class of this star? [0.5]
    G7V
    (b) This star was discovered to have a companion using the transit method. To the nearest hundredth of a magnitude, what was the amplitude of the transit curve? [0.5]
    0.03 M
    (c) To two significant figures, what is the approximate density of the companion? [1]
    1.50 $\frac{g}{cm^3}$

26. Consider the star 2M1207: [2]
    (a) What image shows this DSO? [0.5]
    Image 1
    (b) In what wavelength range is the image taken? [0.5]
    Radio
    (c) What is notable about this DSO? [0.5]
    A protoplanet was visibly discerned.

    By what telescope/program (full name) was this DSO first discovered? [0.5]
    2-Micron All-Sky Survey
27. Consider image 11: [1]
    (a) What DSO is shown in this image? [0.5]
    Beta Pictoris
    (b) In what wavelength range, NIR, MIR, or FIR, is this image taken? [0.5]
    NIR
28. Consider image 8: [2]
    (a) What DSO is shown in the image? [0.5]
    HD 209458b
    (b) This DSO was first discovered by the transit method in September, 1999. Later, in 2005, it was observed directly by what telescope? [0.5]
    Spitzer Space Telescope
    (c) The period of the DSO was also determined from measurements by what telescope? [0.5]
    Hipparcos
    (d) To two significant figures, what is the temperature of the DSO? [0.5]
    1100°K
29. Consider image 10: [4]
    (a) What DSO is shown in the image? [0.5]
    HD 189733b
    (b) In what wavelength is this image taken? [0.5]
    X-ray
    (c) What other image shows this DSO? [0.5]
    Image 2
    (d) In what wavelength is this image taken? [0.5]
    Ultraviolet, Optical
    (e) Through what methods were this DSO detected? [1]
    Spectroscopy, transit, polarimetry, reflection/emission modulations
    (f) What is the X-ray irradiance, to the nearest power of ten, on this DSO? [1]
    $10^3 \frac{\text{W}}{\text{m}^2}$

30. Consider image 6: [2]
    (a) What DSO is shown in the image? [0.5]
    TW Hydrae
    (b) In what wavelength range is the image taken? [0.5]
    Sub-millimeter
    (c) For which of the following attributes - mass, radius, luminosity, temperature - does the object in the center of this image exceed the Sun's respective attributes? [0.5]
    Radius only
    (d) TW Hydrae b, a protoplanet, was found to be false in 2008. What phenomenon was proposed to explain the data that led to the false identification? [0.5]
    Starspots
31. Consider image 3: [2]
    (a) What DSO is shown in this image? [0.5]
    GJ 1214b
    (b) For which of the following attributes - semi-major axis, orbital period, orbital speed, mass, radius, density, temperature, sutface gravity - does the object marked "Planet b" in this image exceed the Earth's respective attributes? [1]
    Orbital speed, mass, radius, and temperature
    (c) What special form of ice may exist on this planet? [0.5]
    Ice VII
32. Consider the HII region N159: [4]
    (a) What image shows this DSO? [0.5]
    Image *xxx*
    (b) What notable bipolar nebula is found in this DSO? [0.5]
    Papillon Nebula
    (c) What subregion of N159 is shown in the image? [0.5]
    N159A
    (d) Identify the three compact sources shown in this image. [0.5]
    N159A5, N159A6, N159A7
    (e) Describe the location, number, and spectral class of the stars that ionize this subregion of N159. [1]
    There are two stars, located in the center of the image, that ionize the subregion. They are O5-O6 and O7-O8, respectively.
    (f) Approximately where does this subregion of N159 lie along the stellar evolutionary track? Why? [1]
    N159A represents a very early stage of star formation, as there are compact systems still embedded in diffuse nebular regions.

Section 3: Astrophysics

Instructions: There are 4 questions in this section, each worth 6 points. Remember to show all work and box your final answer.

33. Consider an alien civilization trying to detect our planet from the wobbles of the Sun. Assume that the Earth is the only planet orbiting the Sun.

   (a) By how many Angstroms does the H-α emission line of the Sun vary due to the Earth if the Earth is viewed at an inclination angle of $\theta = 45°$? [4]

   Over the course of one year, the Earth moves a total distance of $d = 2\pi R$. The radial velocity of the Sun is them given by:

$$v = \frac{d}{T} \cdot \frac{m}{M}$$
$$v = \frac{2\pi m R}{MT}$$

   At an inclination of θ, the doppler shift is:

$$z = \frac{v \sin\theta}{c}$$
$$\delta = \frac{2\pi m R \sin\theta}{McT} \cdot \lambda$$

   Plugging in the numbers, we get that the total variance $\Delta = 2\delta$, is $\boxed{\Delta = 2.8 \cdot 10^{-7}\text{Å}}$.

   (b) Would this wobble be feasibly detected with our current technology? [1]

   No.

   (c) Would the wobble due to Jupiter be feasibly detected with out current technology? [1]

   Yes. (planets have been discovered with their star having wobbles of around 3 meters per second)

34. Consider our star, the Sun.

   (a) Estimate the total energy, in Watts, radiated by the Sun as a protostar, assuming that it has constant density and all energy goes into radiation. [3]

   The energy emitted by a protostar comes from the gravitational potential energy as it collapses. The mass of the Sun is $M = 1.99 \cdot 10^{31}$kg and the radius is $R = 6.96 \cdot 10^{8}$m. We can assume that the Sun starts out very large. The total potential energy gained from the collapse is then:

$$\begin{aligned} E &= E_{init} - E_{fin} \\ &= 0 - \int_0^R -\frac{G}{x} \cdot \frac{M(\frac{4}{3}\pi x^3)}{\frac{4}{3}\pi R^3} \cdot \frac{M(4\pi x^2)}{\frac{4}{3}\pi R^3} \mathrm{d}x \\ &= -\int_0^R -\frac{3GM^2x^4}{R^6} \mathrm{d}x \\ &= \frac{3GM^2}{5R} \end{aligned}$$

   Plugging in the numbers, we get $\boxed{E = 2.28 \cdot 10^{43}\text{J}}$.

(b) Estimate the time, in years, the Sun spends as a protostar, assuming that its average luminosity is equal to its current luminosity. [2]

The current luminosity of the Sun is $3.85 \cdot 10^{26}$W. We have:

$$t = \frac{E}{L}$$

Plugging in the numbers, we get $\boxed{t = 1.88 \cdot 10^9 \text{ years}}$.

(c) Is this too large or too small? [1]

Too large.

35. A star's light curve is observed to dip at regular intervals for 4.2 hours at a time by 1.5%. The star itself is a main sequence G0 star with mass, radius, temperature, and luminosity similar to the Sun. It is determined that the light curve variation is due to a planet that orbits the star and that the planet crosses directly in front of the star.

(a) What is the radius, in meters, of this planet? [2]

Since the planet covers 1.5% of the star's surface, we have:

$$\left(\frac{r}{R}\right)^2 = 0.015$$
$$r = \sqrt{0.015}R$$
$$r = 0.12R$$

Plugging in the numbers, we get $\boxed{r = 8.5 \cdot 10^7 \text{m}}$.

(b) What is the orbital period, in days, of this planet? [3]

Over the duration of the transit, we can assume that the planet travels in an approximate line across a diameter of the star, that the star-planet distance is much less than the observer-system distance, and that the planet is much smaller than the star. We have:

$$vt = 2R$$
$$v = \frac{2R}{t}$$

Now, since the planet is in orbit around the Sun:

$$\frac{GMm}{d^2} = \frac{mv^2}{d}$$
$$v^2 = \frac{GM}{d}$$
$$\frac{2\pi d}{v} = \frac{2\pi GM}{v^3}$$
$$T = \frac{\pi GMt^3}{4R^3}$$

Plugging in the numbers, we get $\boxed{T = 123 \text{ days}}$.

(c) What type of planet is this? [1]

Cool Jupiter.

36. A planet of radius $r = 1.23 \cdot 10^7$m orbits a star of luminosity $L = 1.23 \cdot 10^{26}$W at a distance $R = 1.23 \cdot 10^{11}$m. The planet is a rocky planet with a cloudy atmosphere. The albedo of its atmosphere (in and out) is $\alpha = 0.5$ and the albedo of its surface is $\beta = 0.1$. The atmosphere ensures that the planet has uniform temperature. Assuming that the planet acts as a perfect blackbody, what is the temperature T, in Kelvins, of the planet?

The flux of sunlight reaching the planet is given by:

$$\begin{aligned} L' &= L \cdot \frac{\pi r^2}{4\pi R^2} \\ &= \frac{Lr^2}{4R^2} \end{aligned}$$

Now, denote the flux absorbed by the surface of the planet by L''. We have:

$$\begin{aligned} L'' &= L'(1-\alpha)\big((1-\beta) + \beta\alpha(1-\beta) + (\beta\alpha)^2(1-\beta) + \dots\big) \\ &\quad + L''\big(\beta\alpha(1-\beta) + (\beta\alpha)^2(1-\beta) + \dots\big) \\ &= \frac{(1-\alpha)(1-\beta)}{1-\alpha\beta}L' + \frac{\alpha\beta(1-\beta)}{1-\alpha\beta}L'' \\ \frac{1-2\alpha\beta+\alpha\beta^2}{1-\alpha\beta}L'' &= \frac{(1-\alpha)(1-\beta)}{1-\alpha\beta}L' \\ L'' &= \frac{(1-\alpha)(1-\beta)}{1-2\alpha\beta+\alpha\beta^2}L' \end{aligned}$$

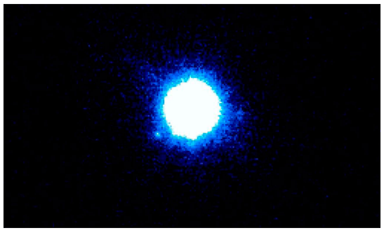
From the Stefan-Boltzmann law, we have:

$$\begin{aligned} L'' &= 4\pi\sigma r^2 T^4 \\ T &= \Big(\frac{L''}{4\pi\sigma r^2}\Big)^{\frac{1}{4}} \\ &= \Big(\frac{(1-\alpha)(1-\beta)}{1-2\alpha\beta+\alpha\beta^2} \cdot \frac{L}{16\pi\sigma R^2}\Big)^{\frac{1}{4}} \end{aligned}$$

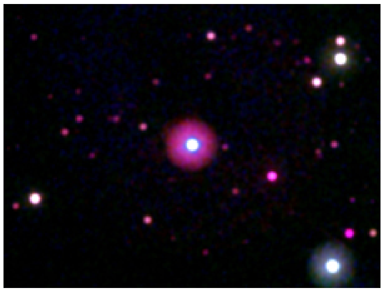
Plugging in the numbers gives us $T = \boxed{194°\text{K}}$.

You might feel that this test was too long and too hard for a single person to do in 50 minutes, and yes, it is quite unreasonable. You might really want that score of 69, but you know what? Stop wanting that 69 so much - it's indecent - and it'll be harder to get than an actual 69.

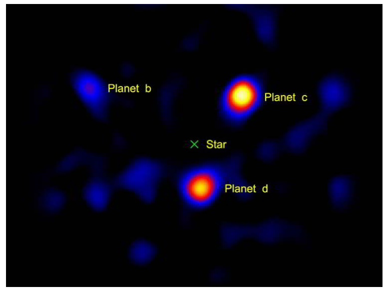
Image Sheet



2M1207



HD189733



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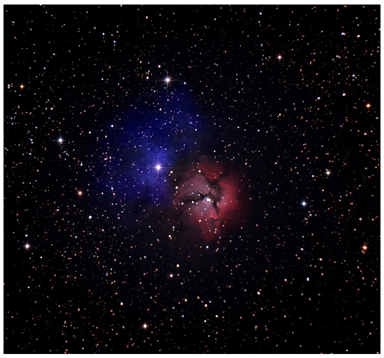

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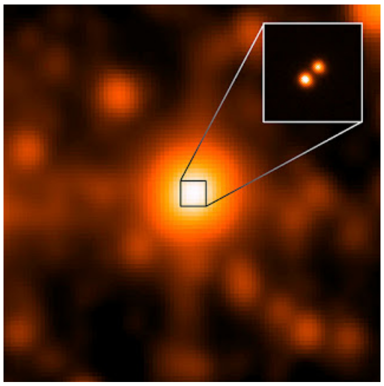
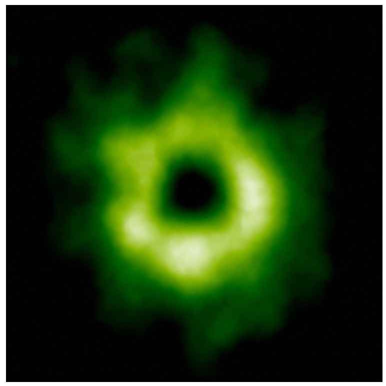
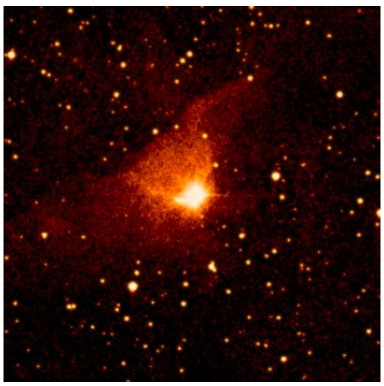


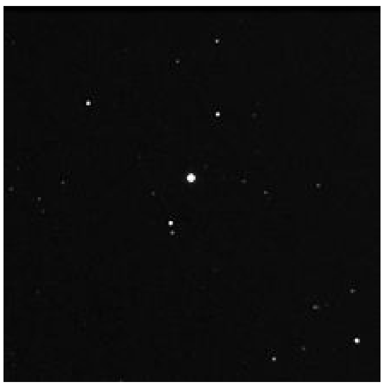
Luhman16



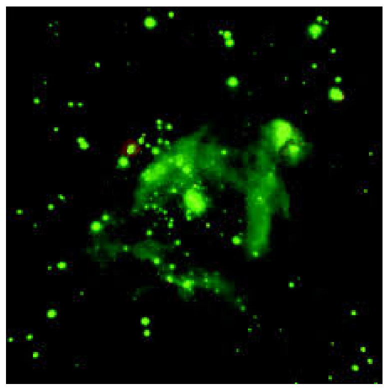
TW Hydrae



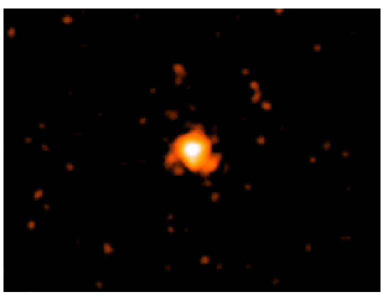
FU Orionis



HD209458



N159



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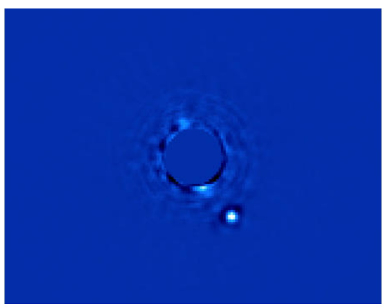

β Pictoris

I don't know why I decided to LaTeX this test. It was very painful.