2012 New York State Science Olympiad
Astronomy - Event #2

1. Application of Physical Principles to the Detection of Exoplanets
    a. Explain how the Doppler Effect can be used to detect exoplanets (3 points)

(3) - Mention that you can detect "wobble" of stars based on periodic redshifting of the star's spectral lines

    b. Explain how exoplanets can be detected as they transit a star (2 points)

(1) - show understanding that a planet transit occurs when a planet passes between an observer and a star
(2) - we can detect this as periodic dimming of a star's light, and can figure out how quickly they orbit

    c. Which space telescope, launched in March 2009, detects exoplanets using both of these methods? (2 points)

(2) - Kepler

    d. What three constellations is the spacecraft surveying? (1 point apiece, 1 point for all three)

(1) - Cygnus
(1) - Lyra
(1) - Draco

    d. Explain the need for a long mission lifetime for Kepler, and discuss why only short-period planet candidates were initially found (4 points)

(2) - The telescope must be able to detect multiple transit events in order to establish a pattern.
(1) - This necessitates multi-year missions to detect Earth-like planets around Sun-like stars
(1) - Only short-period examples were found initially because those transit profiles were established more quickly (more data points)

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2. Variable Stars - General Proficiency

a. Label the approximate locations/regions of the following classes of variable stars on the H-R diagram below: Classical Cepheid, RR Lyrae variable, W Virginis subclass, RV Tauri subclass, Yellow Hypergiant, Mira variable, Alpha Cygni variable (1 point each, 1 additional point for having all of them)[1]

SEE ATTACHED DIAGRAM: BE A LITTLE LENIENT WITH EXACT POSITIONING; THE IMPORTANT THING IS RELATIVE POSITION ON THE H-R DIAGRAM

b. Name and describe the mechanism by which Cepheid Variables oscillate--hint: it has to do with the opacity of a particular gas, at different temperatures (5 points)

(1) - Kappa Mechanism
(1) - mention that it's cyclic
(3) - In most stars, opacity decreases as a function of increasing temperature. However, this is not always the case. If a gas for which this doesn't hold is compressed, then it heats up and becomes less transparent. The energy flux outward from that denser region decreases, causing a restoring force, so the star returns to its original state, only to encounter another density perturbation that keeps the cycle going.

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c. Consider 2 Cepheid variables with periods of 4 days and 35 days.

i. What are their absolute magnitudes, within .1 magnitudes? (2 points each)

Students should use a graph, chart, or equation, but no appreciable work need be shown.

(2) - 4 days: -3.5
(2) - 35 days: -5.7

ii. What are the approximate peak radiant wavelengths of those stars, assuming they lie in the center of the Cepheid instability strip? (2 points each)

(2) - Magnitude -3.5: ~K0 spectral class, T = 4100K ± 200K
(2) - Magnitude -5.7: ~M3 spectral class, T = 3300K ± 200K

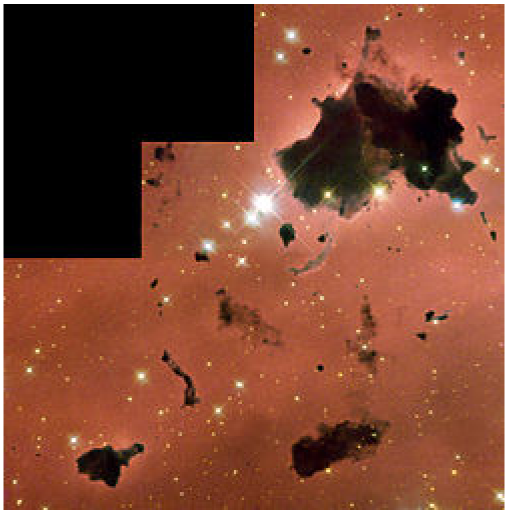
iii. Predict the B-V color indices of these stars (3 points each)

Students should find an appropriate color analogue for each star, and use that star's value for *B-V*.

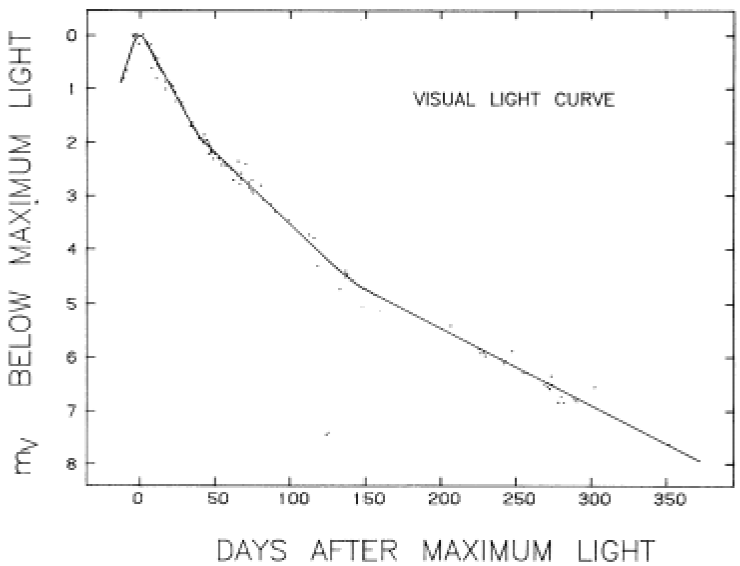
(3) - Magnitude -3.5: between .18 and .78
(3) - Magnitude -5.7: between .48 and 1.10

3. Star Formation and evolution

a. Beside each of the following images, label as a Bok Globule, Herbig-Haro Object, planetary nebula, type I-a supernova, type II-l supernova light curve, type II-p supernova light curve, supernova remnant, Wolf-Rayet star (1 point each):



Bok Globule



Supernova Type I-a

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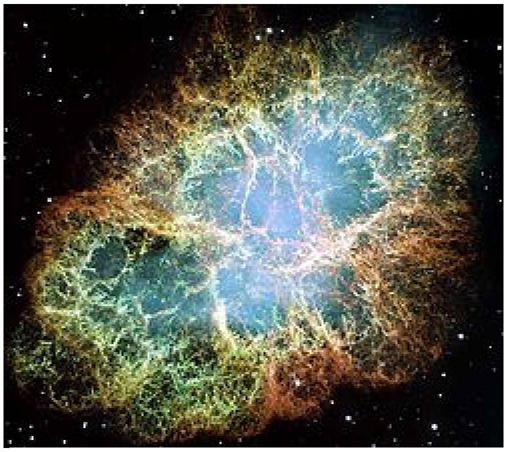
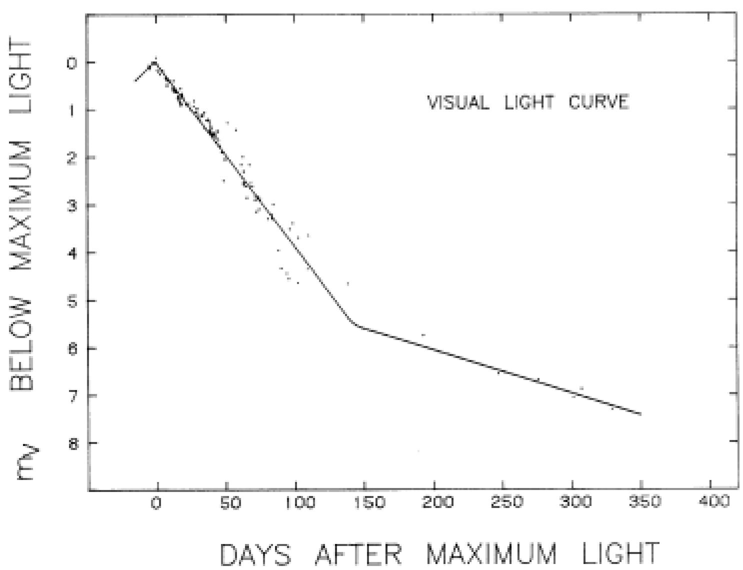
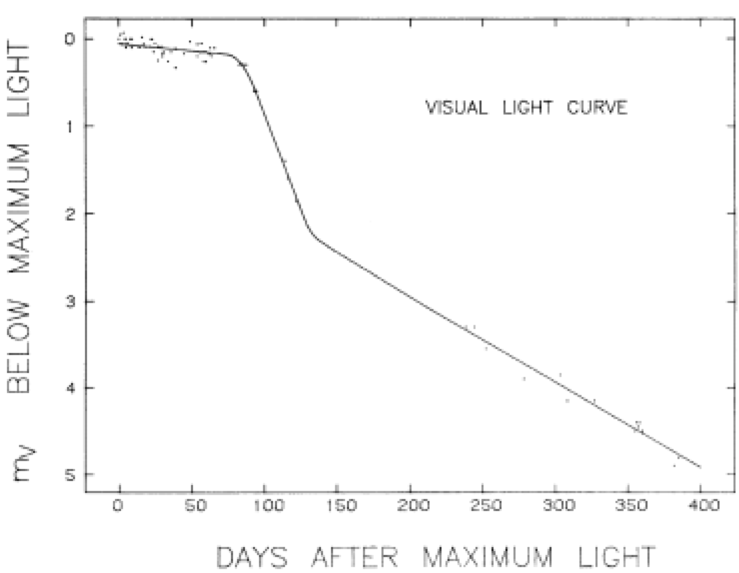


Supernova Remnant



Supernova type I-l



Supernova type II-p

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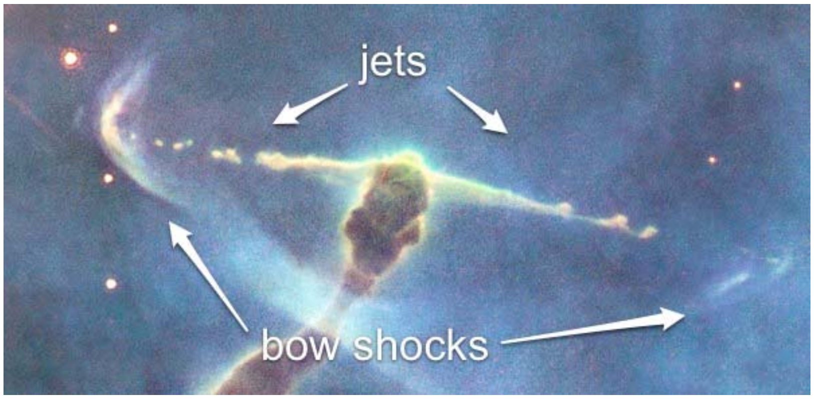
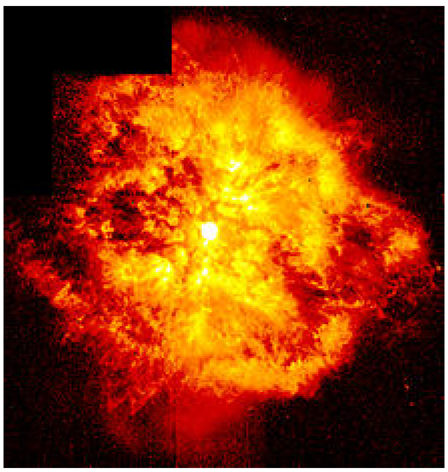


Herbig-Haro object



Wolf-Rayet star

planetary nebula

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b. What is responsible for preventing white dwarves and neutron stars from collapsing into black holes? Hint: the concept is similar, but they are distinct processes (3 points).[3]

(1) - degeneracy pressure from confined particles is responsible for both, as a result of the Pauli Exclusion Principle (only degeneracy pressure is required for the point)
(1) - white dwarves are supported by electron degeneracy pressure
(1) - neutron stars are supported by neutron degeneracy pressure

c. Qualitatively describe how star mass is related to a star's luminosity and lifetime on the main sequence (3 points).

(2) - A higher-mass star will be more luminous, since more radiation pressure is required to oppose gravity and keep the star stable
(1) - More luminous stars fuse hydrogen more quickly, resulting in a smaller lifetime
NOTE: There's math for all this, but it's not important for the purposes of this question

d. Briefly explain why star-forming regions are more likely to be observed in galaxies like the Antennae (3 points).

(2) - The Antennae are undergoing a collision
(1) - This means that gas clouds are interacting with each other, increasing the rate of star formation

e. What are the two most common types of stars in the Milky Way? Why are they mostly unobserved? (4 points)

(2) - white dwarves and red dwarves
(2) - unobserved because they are very dim

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4. Astronomical distance measurements and RR Lyrae stars

a. Consider an RR Lyrae star with a period of .5 days. Obtain a value for its absolute magnitude (2 points).

(2) - As a general rule, M_V for RR Lyrae Stars is about +0.6 (accept answers ±.1)

b. Calculate the distance in parsecs to this hypothetical star, if it appears to have a magnitude of 10. Do not account for interstellar extinction (3 points).[4]

(1) - $d = 10^{1/5(m-M)+1}$
(1) - $d = 10^{1/5(10-0.6)+1}$
(1) - d = 972 pc

c. Convert the distance obtained in part b to light-years, kilometers, astronomical units, and Bohr radii (1 point each)

NOTE: Accept answers within 5%
(1) - 3170.96 ly
(1) - 3.00×10^{16} km
(1) - 2.01×10^{8} AU
(1) - 5.67×10^{29} Bohr radii

d. The parallax of this star is measured to be 1.17 milli-arcseconds. Calculate its distance based on this information (2 points)

(1) - d[pc] = 1/parallax[arcseconds]
(1) - d = 854.7 pc

e. Would you be more likely to find this star in a globular cluster or an open cluster? Explain why (3 points)

(1) - Globular cluster
(2) - RR Lyrae stars are older, and globular clusters tend to contain older stars

f. Briefly describe the impact that the Blazhko effect has on some RR Lyrae-type stars. In what star was it first discovered? (4 points)[2]

(3) - variations in period and amplitude of stellar brightness
(1) - first observed in RW Draconis

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5. General Information about Astronomical Objects

a. Give the coordinates of the following objects, in RA (±10 arcseconds), Dec (±10 arcseconds), and distance from the solar system, in lightyears (where indicated, ±100 ly) (.5 points per piece of information)

Object	RA	Dec	Distance
RX J0806.3+1527	08h 06m 23.20s	15□ 27’ 30.20”	1600
Rosette Nebula	06h 33m 45s	04□ 59’ 54”	5200
CH Cygni	19h 24m 33.07s	50□ 14’ 29.1”	800
M15	21h 29m 58.38s	12□ 10’ 00.6”	33600
Carina Nebula	10h 45m 08.5s	-59□ 52’ 04”	N/A
U Scorpii	16h 22m 30.78s	-17□ 52’ 42.8”	N/A

b. Give the constellation in which the following objects are located (.5 points per object)

Object	Constellation
DEM L238	Dorado
SNR 0509-67.5	Dorado
NGC 2440	Puppis
Tycho’s Supernova Remnant	Cassiopeia
Kepler’s Supernova Remnant	Ophiuchus
The Mice	Coma Berenices

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c. Match each of the following spectral classes with the color that a star of that class would appear to the human eye, and the representative example of that spectral class (colors may be used more than once, .5 points per piece of information).

COLORS: RED, YELLOW, WHITE, BLUE
EXAMPLE: Spica, SIMP 0136, Canopus, Epsilon Eridani, WISE 1828+2650, Sigma Orionis A, Sol, Vega, Barnard's Star, V838 Monocerotis

Spectral Class	Color	Representative Example
O	Blue	Sigma Orionis A
B	Blue	Spica
A	Blue/White	Vega
F	White	Canopus
G	White/Yellow	Sol
K	Yellow	Epsilon Eridani
M	Red	Barnard's Star
L	Red	V838 Monocerotis
T	Red	SIMP 0136
Y	Red	WISE 1828+2650

d. Draw V838 Monocerotis as it appeared in May 2002, and as it appeared in February 2004 (4 points).

Illustrations should look like the image at
http://en.wikipedia.org/wiki/File:V838_Monocerotis_expansion.jpg
Emphasis should be placed on the expansion of the dust cloud (the “light echo”)

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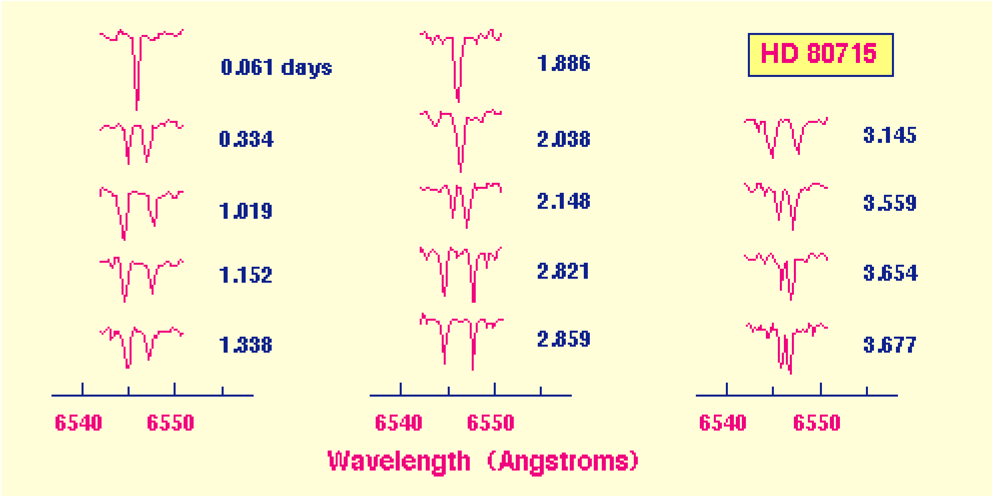
6. Application of Mechanical Concepts



a. Consider a system of two identical stars in mutually circular orbits, with a time-dependent absorption pattern illustrated above. As time progresses, why does the spectral line at 6545 Angstroms seem to split and then recombine? What can we infer about the period of the binary system? (5 points)

(2) - We are observing the shift in each star's spectrum at 6545 Angstroms due to the Doppler Effect
(1) - We can infer that a half-period goes from t = .061 days to t = 1.886 days
(2) - So a whole period is twice the difference, or T = 3.65 days (315360 sec)

b. From this data, what is the approximate orbital velocity of the two stars? (4 points)

(1) - The change in wavelength is about .3 Angstrons (accept between .2 and .4)
(1) - For the the wavelength change much lower than the wavelength, the following relation holds:

$$\frac{v}{c} = \frac{\Delta\lambda}{\lambda_0}$$

(1) - Rearrange and solve for v:

$$v = c \cdot \frac{\lambda}{\lambda_0}$$

(1) - Plug in values for c, λ, and λ_0: v = 1.37 x 10^4 m/s

c. Estimate the radius of the stars' orbit around their mutual center of mass, in astronomical units (3 points)

(2) - Circumference of the circular orbit of each star is 2πr. So v = C/T.
(1) - Solve for r: $r = \frac{vT}{2\pi}$
(1) - Plug in values for v and T from above, obtain r = 6.88 x 10^8 m

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