Reach for the Stars/ Astronomy

[Division B/C]

Georgia Tech Event Workshop Series
2024-25

01 RULES SHEET

02 DIFFICULT TOPICS

03 PRACTICE QUESTIONS

04 TIPS FROM A VETERAN

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The Rules Sheet

- Every single word mentioned even briefly should be somewhere in your notes, and even some topics that aren't mentioned
- [Div C] JS9 usually doesn't come up until higher level tournaments, but if you have the time, even the basics gets you far
- Pay attention when it says "not limited to" they may test you on other objects not listed!
- Spam specific object images! ID is free points AND the most important step
- Sections: Specific Objects, General Astronomy, Math/Physics, [Div C] JS9

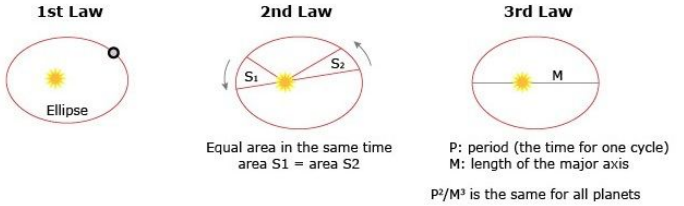
i. Aquila: *Hulse-Taylor Pulsar*
ii. Canis Major: *Sirius*
iii. Cassiopeia: *Cassiopeia A*
iv. Cetus: *Mira*
v. Cygnus: *Cygnus X-1, SS Cygni*
vi. Dorado: *SN 1987A*
vii. Draco: *NGC 6543*
viii. Lyra: *RR Lyrae*
ix. Ophiuchus: *SN 1604*
x. Orion: *Betelgeuse*
xi. Southern Hemisphere: *GW150914*

b. Participants will be required to demonstrate their knowledge of **late-stage stellar evolution and stellar remnants** by answering questions pertaining to the following topics:
   i. Structure, physical properties, and behavior of the following stages of post-main-sequence stellar evolution and stellar remnants: **red giant branch, asymptotic giant branch, planetary nebulae, white dwarfs, supernovae (all types/subtypes), neutron stars, pulsars, and black holes**
   ii. **Orbits, behaviors, and potential evolution (mass transfer, orbital decay, etc.) of objects in compact binary systems, including (but not limited to): novae, dwarf novae, x-ray binaries, neutron star binaries, and black hole binaries**
   iii. Observation and classification of **post-main-sequence stars and stellar remnants** by spectra, light curves, and physical parameters, including (but not limited to): temperature, luminosity, and mass
   iv. Scientific and engineering design principles associated with the following observatories: JWST, Hubble, Spitzer, Chandra, **Swift**, **Fermi**, and **LIGO**

3. **THE COMPETITION:** Using information which may include Hertzsprung-Russell diagrams, spectra, light curves, motions, cosmological distance equations and relationships, stellar magnitudes and classification, multi-wavelength images (gamma-ray, X-ray, UV, optical, IR, radio), charts, graphs and JS9 imaging analysis software, teams will compete in activities and answer questions related to:
   a. Stellar evolution including stellar classification, spectral features and chemical composition, luminosity, blackbody radiation, color index and H-R diagram transitions, H I/II regions, molecular clouds, proto-stars, Herbig-Haro Objects, T Tauri variables, Herbig Ae/Be stars, planet formation, brown dwarfs, protoplanetary disks, debris disks, and exoplanets including but not limited to gas giants, **Neptunes, sub-Neptunes, super-Earths,** and terrestrial planets.
   b. Use orbital mechanics, Kepler's laws, rotation and circular motion to answer questions relating to the orbital motions of planetary systems; use parallax, spectroscopic parallax, and the distance modulus to calculate distances to stars and planetary systems; use the radial velocity, transit, and direct imaging methods to determine properties of exoplanets, use the radiation laws to answer questions relating to planetary surface temperatures and habitability.
   c. Identify and answer questions relating to the content areas outlined above for the following objects: **Orion Nebula, 30 Doradus, HD 80606b, WASP-17b, WASP-121b, LTT 9779b, GJ 1214b, K2-18b, TOI-270d, LHS 3844b, and systems: PSR B1257+12, WD 1856+534, 55 Cancri, Kepler-62, AU Microscopii, Epsilon Eridani.**


DIFFICULT
TOPICS

Topic 1: Physics [Div B]



- My recommendation: get the formulas (units are very important!!!!), find out what all the variables stand for, understand the relationship it is establishing
- Ex: Kepler's laws: 3rd Law $T^2 = \frac{4\pi^2}{GM}a^3$ is incomprehensible alone. Tests will try to overwhelm you with info - just plug in numbers where they should go, and a lot of it will fall into place.
- Part of that is recognizing what is a measure of period (answer: time), what is the gravitational constant (unit of (N * m^2) / kg^2) - recognizing units and where they go in the formula
- Remember that any physics is useful physics!

$$F = G\frac{m_1 m_2}{r^2},$$

v. Basic algebraic understanding of the following concepts using order-of-magnitude estimation, proportions, and scaling relations. **Exam questions should NOT require a calculator to complete.**
(1) The relationship between stellar temperature, radius, and luminosity
(2) Magnitude and distance scales, **including period-luminosity relations and standard candles**
(3) Orbital mechanics and gravitational interaction using Newton's law of universal gravitation, Kepler's laws, the vis-viva equation, and **Schwarzschild radius estimation**

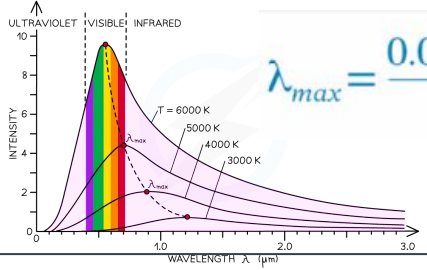
$T^2 = \frac{4\pi^2}{GM}a^3$

can be expressed as simply

If expressed in the following units:

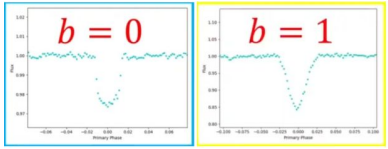
T	Earth years
a	Astronomical units AU (a = 1 AU for Earth)
M	Solar masses $M_\odot$

Topic 2: Physics+ [Div C]



$$\lambda_{max} = \frac{0.0029\ m \cdot K}{T}$$

- Same as for Div B - make sure you know how and when to use the formulas, don't just dump them into your notes and INCLUDE UNITS!!!
- Take a physics class :)
  - Specifically helpful for Kepler's Laws/rotation/circular motion/orbits



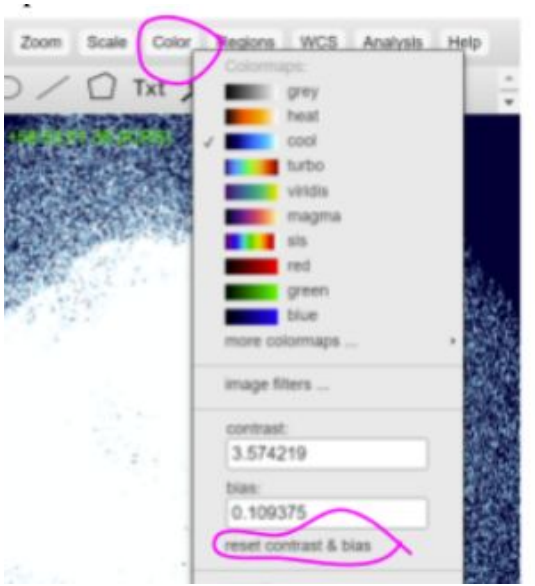
- Note that to some extent (like with circular orbits), you can sometimes find the answer to physics problems using simple geometry formulas.
  - Ex: Period is time for a full orbit; if you have the radius of orbit and you can find orbital velocity, then you have speed and circumference = distance/time and distance, solve for time
- Same with distances - parallax is kind of just trigonometry but with ridiculously small angles

b. Use orbital mechanics, Kepler's laws, rotation and circular motion to answer questions relating to the orbital motions of planetary systems; use parallax, spectroscopic parallax, and the distance modulus to calculate distances to stars and planetary systems; use the radial velocity, transit, and direct imaging methods to determine properties of exoplanets, use the radiation laws to answer questions relating to planetary surface temperatures and habitability.

- Note, "Radiation laws" ⟶ Wien's Law, Stefan-Boltzmann Law, luminosity, magnitude

Topic 3: JS9 [Div C]

- Don't be scared of JS9 - a little preparation goes a long way
- **Very useful resource:** **https://chandra.harvard.edu/js9/index.html** - work through "Guide for using JS9" (Pt. 1 and 2), do some of the other activities
  - Don't just copy-paste, actually go through the activities in the guide!
  - Note: Actual competition interface might be https://js9.si.edu/ or https://js9.si.edu/js9/js9.html (basically same, loading in images is slightly different)!
- Write down how to do things and where to find buttons in your notes - annotated screenshots are great
- For image metadata, look at the FITS header
  - File → display → FITS header
  - Includes observation date/time, telescope, instrument, obs. ID, object name, title of proposal of observation, etc.



Note: trying to pan around the image will just mess up the colors
To fix: Color (in top menu)→ reset contrast & bias

PRACTICE QUESTIONS

All of the following questions have been pulled from past YJI exams (which can be found on our website) or the Text Exchange on SciOly Wiki

Question 1

$$\log_b(a) = c \iff b^c = a$$

Q1: Provide a 2-3 step explanation of how you can derive the distance modulus (third equation) from the formulas for flux.
F1 is flux 1, F2 is flux 2, m2 is magnitude 1, m1 is magnitude 2
F is flux, L is luminosity, D is distance in parsecs
M is absolute magnitude, m is apparent, r is radius/distance in parsecs from Earth

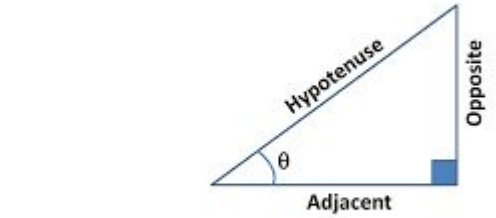
$$\frac{F_1}{F_2} = 10^{(m_2 - m_1)/2.5}$$

$$F = \frac{L}{4\pi D^2}$$

$$m - M = 5\ log_{10}\left(\frac{r}{10}\right)$$

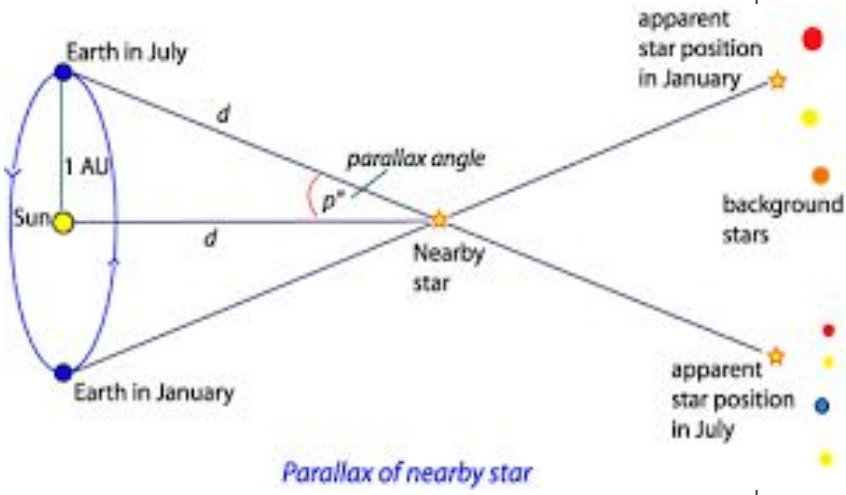
Hint: taking the square root is the same as going to the ½ power
Hint 2: Absolute magnitude is the magnitude from a distance of 10 parsecs away
Hint 3: Apparent magnitude is the magnitude as seen from Earth

Question 2



Q2: Parallax is usually measured in arcseconds. If a star has a parallax of 0.2 arcseconds, how far is this star from the Sun in parsecs?
1 degree = 3600 arcseconds
1 parsec = 206265 AU

Hint: Distance from Earth to Sun is 1 AU
Hint 2: don't forget to convert units!
Hint 3: "parallax" is the parallax angle p in the diagram to the right →



Common Questions

What stage of stellar evolution is the Sun in right now?

Main sequence

Identify the stellar object in the top right. What nebula is it in?

Mystic Mountain, in Carina Nebula

Which of these phases is most likely to immediately follow a (small) red giant:

A. Planetary nebula B. white dwarf C. neutron star D. black hole

What stellar object can produce a Type 1a supernova, and when does it occur?

White dwarf, when it exceeds Chandrasekhar mass limit

What is the heaviest element produced by nuclear fusion?

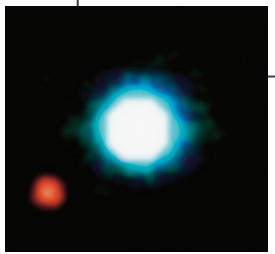
Iron

Tips from a Veteran

- Note-taking for specific objects: know statistics, what makes them special, fun facts, what kind of object they are. And a BILLION images, more than you think you need
- You NEED a formula/constants/conversions sheet for math (esp Div C)
- Usually, tests run long and difficult - split up work, make sure you answer every single multiple choice (just guess!), then spend remaining time on long math problems. Don't get hung up on problems, check worth if it's taking too long
- Personal process: I handled multiple choice, specific object questions, general astronomy topics. My partner did the math problems, and JS9 if they had it
    - This is a good way to split up doing tests, a very bad way to split up taking notes/preparation (i.e. very unfair to the person taking notes on all of the specific objects & all of general astronomy)

Tips from a Veteran

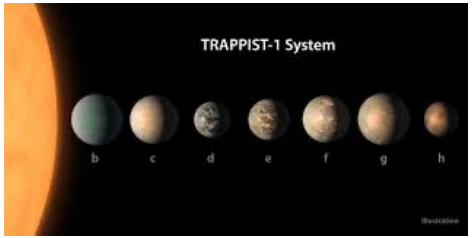
- Tests may care about information concerning specific photos as well
  - Ex: it may ask to identify a nebula, then in what light wave it was taken in, or what telescope was used to photograph it, or even when it was taken (not necessary knowledge but you can kind of tell the wavelength from the photo's colors)
- Make sure to also research if your specific objects have different names/have smaller parts within them! You'll find many more photos/info, and having knowledge about the parts within the object is important
  - Ex: Keyhole Nebula or Cosmic Cliffs are WITHIN the Carina Nebula - many photos of the "Carina Nebula" are actually specific parts of it



Tips from a Veteran

- Make sure you have thorough notes on very important stellar objects!! (ex: the Sun, Earth, Solar System - have the mass, radius, magnitude, classification, orbital radius, period, etc) Example questions: absolute magnitude of sun?
- Stellar Evolution & classification is also an extremely important topic, just generally easier than physics
- Make sure to check that your information is updated/credible/has not been disproven!
- Do too many practice tests, but also make sure to write down what you lack or got wrong! This is a great way to see what you're missing
- [Div C] Take advantage of computers! Hyperlink stuff! Save the trees!
- Take real, solid, thorough notes - not just ChatGPT or copy-pasting Wikipedia. If you blindly copy-paste, you won't understand anything on the test - won't know where to look, what to look for, what any of your "notes" mean

Disclaimer:



- I may be mildly overstating the importance of physics to Astronomy
- ID is still probably a good ¼ to ½ of your points
- General astronomy is going to be another ⅓ to ½ of your points
- Physics is usually ⅓ or less - but also often the difference-maker and the hardest points to earn (basically, a tie-breaker)
- Also, depending on what competitions you go to - JS9 often doesn't show up at all (personally last year JS9 wasn't on my local invitationals, regionals, or state)
- Hopefully you will have all the notes and photos and knowledge to answer everything else on the test already! Physics is just a little more involved than Ctrl + F
- It is still much more important that you get solid notes on every other topic, and can comfortably identify every specific object (I'm talking having every image in existence of that exoplanet in your notes, "artistic interpretation" or not)
- Hopefully I didn't scare you off of astronomy yet! I promise it's cool!

Additional Resources

Chandra website!!!

https://chandra.harvard.edu/edu/olympiad.html

https://chandra.harvard.edu/edu/

https://chandra.harvard.edu/js9/index.html

https://apod.nasa.gov/cgi-bin/apod/apod_search

You might already know this one but: https://scioly.org/tests/
Practice tests! Just Ctrl + F for all astronomy/reach for the stars tests
(also more here! https://scioly.org/wiki/index.php/Scioly.org:Test_Exchange#Tournament-Released_Sets)

For specific objects: press/image releases from telescopes/NASA/ESA

The descriptions in image releases are one of the best sources of specific but still readable information about the objects!

THANKS!