

# PHYSICS 313 - Winter/Spring Semester 2017 - ODU

## **Astrophysics - Problem Set 9 – DUE Tuesday, March 28**

Please submit your solution using the following format. You can submit it as an email to [skuhn@odu.edu](mailto:skuhn@odu.edu) anytime before midnight on the day on which the Problem Set is due; in this case, you **must** use an electronic file format (like MS Word, LaTeX, .pdf, Mathematica etc.) or simple text (follow the rules of some programming language like Fortran or C to write mathematical expressions like  $x**2$  for the square of  $x$  etc.). Alternatively, you can write your solution by hand on paper and turn it in **in class** on the same day (no late submissions); please write clearly and cleanly!

For each problem (part), type the problem number (e.g., “1a.” or “2c”), followed by a space, and then your solution. For “yes/no” questions, enter “Y” or “N”, for multiple choice questions, enter the correct choices (“1” or “3” or...) without any additional characters, and for numerical questions, quote the result in the form “3.1415” or “3.1415e12”. For conceptual questions, just write the text (no special formatting needed). Some problems require mathematical derivations or equations in addition to text or numbers (clearly stated in the problem text). **Only** for those cases may you use a **clean** scanned image of a handwritten derivation, included in your electronic submission (if you choose that route).

IN ALL CASES, make sure that your full name appears on all your submissions to guarantee you get credit for your work! Also, do NOT simply copy someone else’s solution (honor code!) – you can ask for help if you get stuck, but you must submit your OWN work. (I will randomly ask questions during class to check whether you understand the solution you submitted..

### **Problem 1**

Mark each of the following items with “Y” or “T” if they can be found in our own galaxy, the Milky Way, and with “F” or “N” if they don’t exist within the Milky Way (including its halo):

- 1a) Individual (unbound, single) quarks.
- 1b) Positrons.
- 1c) Neutrinos.
- 1d) Photons.
- 1e) Some type of dark matter.
- 1f) Hydrogen gas
- 1g) Dust particles.
- 1h) 10 Trillion main sequence stars.
- 1i) White dwarfs.
- 1j) Planets.
- 1k) Neutron stars.
- 1l) Sun-mass black holes.
- 1m) (At least one) supermassive black hole.
- 1n) Quasars.
- 1o) Globular clusters.
- 1p) Magnetic fields.
- 1q) Spiral arms.
- 1r) Central bulge.
- 1s) Noodles.

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### **Problem 2**

The following is a set of multiple choice questions. Answer each with a single digit:

2a) Which of the following statements about the Milky way is correct?

- 1 – Stars in the spiral arms collide with each other all the time.
- 2 – Most stars in the disk are moving roughly with the same speed.
- 3 – A star that is born in a spiral arm stays within that same arm for all of its life.
- 4 – Our galaxy contains no black holes with more than 10 solar masses.

2b) Which of the following types of electromagnetic radiation is **unsuitable** to observe the center of our galaxy?

- 1 – Infrared radiation
- 2 – Radio waves
- 3 – Visible light
- 4 – x-rays.

### **Problem 3 – Show your work (not only final results)**

Some halo stars and globular clusters circle our Milky Way at radii as large as 50 kpc. Assume they move with tangential velocity 200 km/s. Calculate the total mass required for the Milky Way to explain this motion in terms of Keplerian orbits (i.e., assuming a spherical mass  $M$  inside the orbit, calculate the size of  $M$  in units of solar masses,  $2 \times 10^{30}$  kg). Compare this number with the visible luminosity, which is roughly 20 billion times that of the sun.

*Note:* 1 pc =  $3 \times 10^{16}$  m.

### **Problem 4 – Final numerical results suffice, but you may show your work “in case”**

Calculate the Schwarzschild radius of a black hole with mass  $4 \cdot 10^6 M_{\text{sun}}$ . Compare to the following sizes:

- 1) The radius of a star with that same mass above, but only the density of a typical red giant like Betelgeuse ( $10^{-5}$  kg/m<sup>3</sup>; 1/100 millionth the density of water!)
- 2) The diameter of an object that varies on the time scale of 1 hour (assuming that for causality to hold, the object cannot be larger than the distance traveled by light in 1 hour)
- 3) The closest approach of the orbit of star S0-16, which has an orbit with major half axis of 900 AU and an eccentricity of  $e = 0.95$ .
- 4) The resolution of a long-baseline radio interferometer,  $10^{-3}$  arcsec, over the distance from Earth to the galactic center (8 kpc).