PHYSICS 313 - Winter/Spring Semester 2017 - ODU

Astrophysics - Problem Set 8 – DUE Tuesday, March 21

Please submit your solution using the following format. You can submit it as an email to 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 statements with "Y" or "T" if they are correct, and with "F" or "N" if they are incorrect:

1a) Gravitational Waves are too weak to ever be detected.
1b) Every single elementary particle predicted by the Standard Model *) has been found.
1c) The Standard Model can explain every astrophysical observation to date.
1d) Gamma rays cannot be detected directly by satellites.
1e) Gamma rays can be detected by ground-based observatories that look at their interaction with the atmosphere.
1f) Atomic nuclei are made of quarks.
1g) Some cosmic ray telescopes have observed single, isolated quarks from some cosmic source.
1h) Very high energy cosmic rays require fundamental particle detectors to be "seen".
1i) Most high-energy cosmic rays originate from our sun.
1j) There is an upper limit to the energy of protons that travel over long distances (of the order Megaparsecs).
1k) No neutrinos from outside the solar system have been detected yet.

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*) In this problem, the term "Standard Model" refers to the present standard model of particle physics, which includes all fundamental matter particles and their interactions except gravity.

Problem 2

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

2a) Which of the following types of "cosmic rays" can NOT "tell" where they might have originated in the Universe?
1 – Photons
2 – Neutrinos
3 – Protons up to a few thousand GeV energy
4 – The most energetic particles ever observed.

2b) Which of the following particles can change their type (oscillate in flavor) in flight?
1 – Photons
2 – Neutrinos
3 – Protons
4 – Positrons

2c) Which of the following properties do neutrinos have in common with electrons?
1 – Their masses
2 – Their electric charges.
3 – Their spin
4 – Their interaction cross section with matter

2d) Which of the following names for putative new particles did I just make up? (Meaning no "serious" theorist hasn't hypothesized their existence so far)
1 – Axions
2 – WIMPs
3 – Inflatons
4 – Groupons

Problem 3

So far, cosmic rays consisting of protons, nuclei, leptons (and some antileptons), neutrinos and all kinds of electromagnetic radiation (photons) have been detected and studied. Give at least one example for a particle or cosmic ray type that has not yet been observed directly (and unambiguously) and that is not part of the Standard Model, but has been conjectured or predicted to exist by some theorists. Explain in at least 5-10 sentences why the particle is thought to exist, what its presumed properties are, and how scientists are hunting for such particles.