PHYSICS 313 - Winter/Spring Semester 2017 - ODU

**Astrophysics - Problem Set 10 – Solution**

**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)** Relative to their respective sizes, galaxies are much further apart from each other than stars in our solar neighborhood are. **F**

**1b)** Elliptical galaxies are mostly found in complete isolation, far away from any other galaxies. **F**

1c) The very largest elliptical galaxies are probably the result of mergers. **T**

1d) The main difference between Seyfert galaxies and Quasars is that the latter are even more luminous. **T**

1e) The word “Quasar” (or QSO) is used because the object it describes is a particularly bright but otherwise ordinary star. **F**

1f) The luminosity of typical AGNs is due to light directly emitted from the event horizon ($R = R_s$) of a black hole. **F**

1g) Particularly bright (over all wave lengths) and highly variable AGNs probably have jets associated with them. **T**

1h) In the past, there were many more AGNs than there are now. **T**

1i) Galaxies were created in the Big Bang right from the start and haven’t changed since at all. **F**

1j) Supergiants were particularly common in the early years of the universe. **T**

1k) Very young galaxies didn’t contain many white dwarfs. **T**

**Problem 2**

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

2a) Which of the following galaxy types are NOT considered “Active” (or AGN)? **2**

1 – Seyfert galaxies.
2 – Andromeda.
3 – Quasars.
4 – Radio Galaxies.

2b) Which of the following statements about elliptical galaxies is false? **2**

1 – They include the Hubble types E0 through E7.
2 – They typically contain a lot more gas and dust than the Milky Way
3 – Some of the smallest galaxies are ellipticals (e.g., dwarf spheroidals)
4 – Some of the largest galaxies are ellipticals (e.g., cD).

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

What would be the luminosity of a black hole (only an apparent contradiction) that converts one solar mass completely into light every 30,000 years? Compare to the solar luminosity of $3.8 \times 10^{26}$W! (This would correspond to the central black hole in the Milky Way if we assume that it converts 10% of the mass it consumes in a year into light).

**Answ.:** $L = \dfrac{m_{sun} c^2}{30{,}000 \times 3.15 \cdot 10^7 s} = 1.9 \cdot 10^{35} W = 492\,\text{Mio} \times L_{sun}$. So the luminosity of the central black hole could in principle exceed that of the sun by an even larger factor than its mass! (In fact, it seems to be less than the number above. but still hugely bigger than that of normal stars).

**Problem 4** – Show your work (not only final results)

For the black hole in Problem 3, find out what its minimum mass must be so that the luminosity doesn't exceed the Eddington Limit. What would be, in turn, the minimum radius of that black hole? (Of course, "real" supermassive black holes are even bigger…)

**Answ.:** The Eddington luminosity is

$$L_{\max} = \frac{4\pi GMc}{\bar{\kappa}} = \frac{4\pi GMc\, m_H}{\sigma_e} = 3.28 \cdot 10^4 L_{sun} \frac{M}{M_{sun}}$$

Setting $L_{\max}$ equal to the luminosity calculated above yields a mass that is at least 15,000 times the solar mass, or $3 \cdot 10^{34}$ kg. This corresponds to a Schwarzschild radius of 44,300 km, much smaller than the sun itself. (Again, real central black holes are much more massive than that).