ELEC-E4210 Introduction to Space (5 cr) **Exam 14.12.2021**

Answer all four questions. ***IMPORTANT: Always justify your answers.*** *Because you are allowed to use course materials in the exam, you need to show that you have understood the problems, and can explain how you have solved them and reached the final conclusions. Simply stating the answer will not be enough, so always explain what you have done. Write down all the assumptions that you make and other details of how you derive your answer, even and especially if you use software for calculating them. Especially in this home exam you cannot earn full points unless you carefully elaborate (and show!) all the steps needed to get to your conclusion.*

1. Analyse the four solar wind – Solar System object interaction types, (1) Moon-like, 2) Comet-like, (3) Venus-like and (4) Earth-like interactions, and answer the following questions.

a) Describe how these interaction types depend on the properties of the object and give two examples of the objects for every four interaction types (so 8 objects in total). (2p)

b) Give one example of a space mission and one space instrument on that mission (so in total 4 missions and 4 instruments) which have been used to investigate those four interaction types. (2p)

c) What pros and cons (so benefits and limitations) there are to investigate those interaction types with these modelling approaches: (i) a test particle simulation, (ii) an MHD simulation, (iii) a hybrid simulation, (iv) a full kinetic simulation. Justify your answer. (2p)

2. You are on an observing shift in Metsähovi (60° 13' 4.1" N, 24° 23' 35.2" E) from 9 o'clock Finnish time on September 20th to 9 o'clock Finnish time on September 21st.You come to Metsähovi in a hurry and notice that you accidentally took a source list (Table 1) that you used at another observatory earlier in the year, and now you must quickly work out if you can observe these sources during your shift in Metsähovi.

a) Considering that each quasar observation takes about 30 minutes and a solar map can be made in less than ten minutes, which of those four sources, if any, can you observe during your shift?

b) At the same time, your cousin is on an expedition at the North Pole. If he would have a radio telescope similar to the one you are using in Metsähovi, which of the four sources, if any, would he be able to observe?
(6p total)

Table 1.

Source 1. Sun
Source 2. Quasar PKS 0459+060; RA= 05h 02min 15.445s, Dec= +06° 09' 07.494"
Source 3. Quasar B0716+714; RA= 07h 21min 53.448s, Dec= +71° 20' 36.362"
Source 4. Quasar PKS 1424–418; RA= 04h 27min 56.297s, Dec= –42° 06' 19.437"
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3. At Metsähovi Radio Observatory we study very distant sources where radiation is beamed into a narrow cone pointing at us. These objects look point-like on the sky, each with different distance d, and in all of them the radiative power P specific to that source is confined into a solid angle Ω towards the Earth (and because of large distances, even the narrowest light beams reaching us are still much wider than the Earth). We also know the apparent magnitude m_{app} for each source from our colleagues in other observatories.

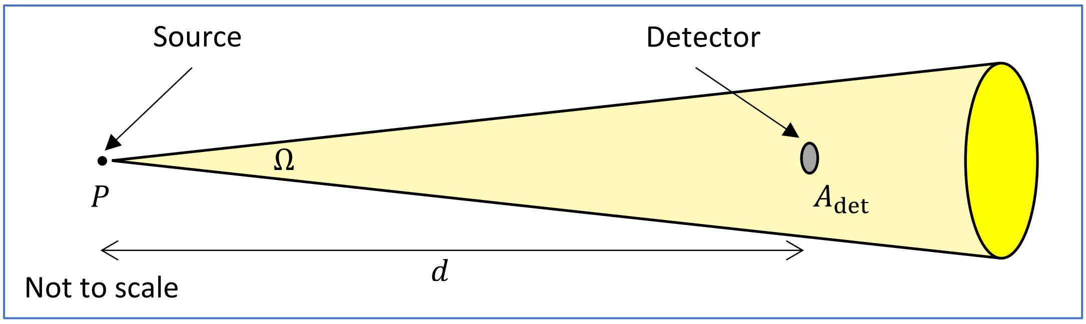
We need to design an instrument that registers all EM radiation hitting it. The observational sensitivity limit requires us to receive at least power P_{det} in order to detect the object; otherwise, it's too faint to be seen. We don't know the size of the instrument yet; the detector area A_{det} will be determined by the budget. (See figure below for parameters.)

Help us to determine the following things:

a) How distant objects (with properties d,P,Ω) can we observe with the detector with properties P_{det} & A_{det}? In other words, derive the equation for distance d at which the instrument receives exactly power P_{det} from the source. (3 p)

b) If the intrinsic radiative power of the object P doubles, what is the change in apparent magnitude m_{app}? (1 p)

c) Assuming the observed radiation is blackbody radiation, how many per-cents would the source temperature need to change for the observed brightness of the source to double? (2 p)



4. A satellite is parked at Low Earth Orbit with perigeum 300 km and apogeum 550 km (above the surface). The mission, however, requires an circular orbit with 750 km perigeum in order to avoid too much atmospheric drag and to reach mission lifetime. The goal is to achieve the desired orbit with minimal amount of fuel and maneuvers.

a) How many speed kicks and with what direction are needed to achieve final orbit? (1p)

b) What is the most effective orbital transfer sequence to desired orbit? (2p)

c) Calculate the needed delta V budget for the proposed transfer. (3p)

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Constants:

Gravitational constant: 6.674×10^{-11} N m^2 kg^{-2}
Mass of the Sun: 1.9891×10^{30} kg
Radius of the Sun : 6.957×10^{8} m
Mass of Mars: 6.4185×10^{23} kg
Diameter of Mars: 6752.4 km
Astronomical unit: 149597870700 m
Light year: 9.461×10^{15} m
Wien's displacement constant: 2.898×10^{-3} m K
Stefan-Boltzmann constant: 5.671×10^{-8} W m^{-2} K^{-4}
Planck constant: 6.626×10^{-34} J s
Boltzmann constant: : 1.381×10^{-23} J K^{-1}
Speed of light in vacuum: : 2.998×10^{8} m s^{-1}