S-92.3146 Radio Astronomy
Exam 26.5.2015

Answer all five questions. Always justify your answers. However, there is no need to write a book, the facts count.

1.
You get free hands to design and implement a telescope for monitoring the total flux density of quasars in the millimeter/submillimeter domain. Tell us at least the following facts:
a) Where would you place the telescope? (1p)
b) What would the diameter of the telescope be? (1p)
c) What other properties would your telescope have? (2p)
d) What kind of properties would the receivers to be placed at that telescope have? (2p)
Shortly justify your answers! For example in b) it is not enough to only mention the diameter in meters.
You may want to make use of Table2 when you answer this question and the following.

2.
a) Aalto University student Sulo Kuukkeli is on observing shift in Metsähovi during the Midsummer weekend (on June 19-21). During his observing shift he notices that the quasars listed in Table1 are flaring at 37 GHz (compared to earlier data), and he would like to get flux density data for them also at higher frequencies. Because in connection to Question1 you have just designed and implemented a state-of-the-art (sub)millimeter wavelength telescope, Sulo contacts you and asks you to observe the sources from Table1 as soon as possible, preferably during the same week.
Can you help Sulo? Justify your answer with assumptions and calculations (for “entertaining” answers no full points will be granted!). (4p)
b) Sulo wants to give you very detailed instructions for carrying out the observations, in case you are not familiar with single-dish blazar observations. What kind of instructions will he give? (2p)

3.
a) Explain what is meant by “space weather” and how the Metsähovi observations can be used to better understand it. (3p)
b) Give (and shortly explain) three different ways to try to find life in the universe. (3p)

TURN OVER, MORE QUESTIONS ON THE SECOND PAGE

4.
a) What do radio observations of neutral hydrogen HI, ionized hydrogen HII, and molecular hydrogen H_2 tell us about the properties of our own Galaxy? (4p)
b) What is a pulsar? (1p)
c) What is cosmic microwave background (CMB) radiation? (1p)

5.
Quasar 3C279 is observed with the Metsähovi radio telescope ($D = 13.7$m, beam efficiency $\epsilon_M = 0.7$, aperture efficiency $\eta = 0.5$). The brightness temperature of 3C279 is $T_B = 5 \times 10^{12}$ K and its filling factor (the fraction of the telescope beam occupied by the source) Ω_S/Ω_A is $1.5{\times}10^{-13}$. What is the antenna temperature T_A caused by 3C279? What is the observed flux density in Janskys? ($T_A = \epsilon_M \frac{\Omega_S}{\Omega_A} T_B$).

Nr	Source	RA 1950.0	Dec 1950.0
1.	0446+112	$04h49m07.67s$	$+11°21'28.00''$
2.	0605-085	$06h07m59.70s$	$-08°34'50.00''$
3.	1637+626	$16h38m28.20s$	$+62°34'44.30''$
4.	2145+067	$21h48m05.46s$	$+06°57'38.60''$

Table 1. Source list for Question1

Observatory	Latitude	Longitude	Altitude (meters)
Ny Ålesund, Svalbard:	78:08:53 N	16:02:35 E	80
Metsähovi, Finland:	60:13:05 N	24:23:38 E	60
Nizhnij Arkhyz, Russia:	43:38:49 N	41:26:26 E	970
Pico Veleta, Spain:	37:04:05 N	03:23:58 W	2870
Albuquerque, New Mexico:	35:05:01 N	106:39:05 W	2124
Mt. Palomar, California:	33:21:00 N	116:52:00 W	1706
La Palma, Canary Islands	28:45:00 N	17:53:00 W	2326
Mauna Kea, Hawaii:	19:50:00 N	155:28:00 W	4214
Arecibo, Puerto Rico:	18:21:14 N	66:45:19 W	496
Cerro Paranal, Chile:	24:51:00 S	70:27:00 W	2635
Parkes, Australia:	33:00:00 S	148:34:01 E	392

Table 2. Locations of some well-known observatories. This may be useful when you answer Question1 and Question2.

Koordinaattijärjestelmät ---Coordinates

Horisonttijärjestelmästä ekvaattorijärjestelmään: ---Horizontal to equatorial

$$\sin h \cos\delta = \sin A \cos a$$
$$\cos h \cos\delta = \cos A \cos a \sin\phi + \sin a \cos\phi$$
$$\sin\delta = -\cos A \cos a \cos\phi + \sin a \sin\phi$$

Ekvaattorijärjestelmästä horisonttijärjestelmään: ---Equatorial to horizontal

$$\sin A \cos a = \sin h \cos\delta$$
$$\cos A \cos a = \cos h \cos\delta \sin\phi - \sin\delta \cos\phi$$
$$\sin a = \cos h \cos\delta \cos\phi + \sin\delta \sin\phi$$

Ylläesitetyistä muunnoskaavoista voidaan johtaa: ---Derived from the previous formulae

$$\cos h = -\tan\delta \tan\phi + \sin a / (\cos\delta \cos\phi)$$

Tähtiaika ---Sidereal time

$$\Theta = h + \alpha$$
$$\Theta = T + 12\mathrm{h} + n \times 4\,\mathrm{min}$$

Juliaaninen päivämäärä: ---Julian date (integer division!)

$$\mathrm{JD} = 367\mathrm{v} - 7(\mathrm{v} + (\mathrm{k}+9)/12)/4 - 3((\mathrm{v} + (\mathrm{k}-9)/7)/100 + 1)/4 +$$
$$275\mathrm{k}/9 + \mathrm{p} + 1721029$$

Kokonaislukujakolaskuina!

Vakioita: ---Constants

Gravitaatiovakio	f, G	6,6732 x 10^{-11} N m^2 kg^{-2}
Normaali putoamiskiihtyvyys	g_n	9,80665 m s^{-2}
Ideaalikaasun moolitilavuus	V_m	22,4136 x 10^{-3} m^3 mol^{-1}
Absoluuttinen nollapiste	T_0	-273,15 °C
Yleinen kaasuvakio	R	8,3143 J mol^{-1} K^{-1}
Normaali paine	p_0	101325 Pa
Avogadron vakio	N_A	6,02252 x 10^{23} mol^{-1}
Valon nopeus tyhjiössä	c_0	2,997924562 x 10^8 m s^{-1}
Elektronin lepomassa	M_e	9,109534 x 10^{-31} kg
Protonin lepomassa	M_p	1,67265 x 10^{-27} kg
Neutronin lepomassa	M_n	1,67492 x 10^{-27} kg
Atomimassayksikkö	u	1,660565 x 10^{-27} kg
Boltzmannin vakio	k	1,380662 x 10^{-23} J K^{-1}
Tyhjiön permittiivisyys	ε_o	8,85419 x 10^{-12} F m^{-1}
Tyhjiön permeabiliteetti	μ_0	1,25664 x 10^{-6} T m A^{-1} 4π x 10^{-7} H m^{-1}
Faradayn vakio	F	96487 C mol^{-1}
Alkeisvaraus	e	1,6021892 x 10^{-19} C
Protonin ja elektronin lepomassojen suhde	m_p/m_e	1836,15
Alkeisvarauksen ja elektronin massan suhde	e/m_e	1,758803 x 10^{11} C kg^{-1}
Planckin vakio	h	6,626196 x 10^{-34} J s
Rydbergin vakio (vety)	R	1,0973731 x 10^7 m^{-1}
Stefan-Boltzmanin vakio	σ	5,6686 x 10^{-8} W m^{-2} K^{-4}
Wienin siirtymislain vakio		0,290 x 10^{-2} m K

$$B_\nu(T) = \frac{2h\upsilon^3}{c^2\left(e^{h\upsilon/(kT)}-1\right)}$$

$$B_\lambda(T) = \frac{2ckT}{\lambda^4}$$

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5 e^{hc/(\lambda kT)}}$$

$$L = 4\pi r^2 F$$

$$F = \sigma T^4$$

$$z = (\lambda - \lambda_0)/\lambda_0$$

$$V = Hr$$

$$z = H \times r / c$$

$$(1+z)^2 = (c+v)/(c-v)$$

$$\lambda_{\max} T = 3 \ [\text{mm K}]$$

1 Jy = 10^{-26} $Wm^{-2}Hz^{-1}$

$$\alpha = \log\frac{S_1}{S_2} / \log\frac{f_1}{f_2}$$

$$\Omega_A = \frac{\lambda^2}{A_e}$$

$$S = \frac{2kT_A}{A_e}$$

$$\Omega_m = \Omega_A - \Omega_M$$

$$\varepsilon_M = \frac{\Omega_M}{\Omega_A}; \varepsilon_m = \frac{\Omega_m}{\Omega_A} = 1 - \varepsilon_M$$

$$\eta = \frac{A_e}{A}$$

$$T_S = \frac{\lambda B_\nu}{2k}$$

$$\Delta T_{SYS} = \frac{T_{SYS}}{\sqrt{\tau B}} \times K_S$$

$$S_{\min} = \frac{2k}{A_e}\frac{T_{SYS}}{\sqrt{\tau B}} K_S$$

$$\Omega_A = \iint_{4\pi} P_n(\theta,\varphi)\sin\theta \, d\theta \, d\varphi$$

$$\text{ikä} = -\frac{\upsilon}{(n-1)\dot{\upsilon}}$$

(ikä = age)

$$\Delta\upsilon = \upsilon\frac{\lambda}{\Delta\lambda}$$