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1 Questions (/10 pts)

There is one, or more, correct answer(s) for each question. Tick the right box(es).

1. The effective area of X-ray telescopes is of the order of:
   - ☐ 30 cm^2
   - ☐ 300 cm^2
   - ☐ 3000 cm^2
   - ☐ 3 m^2
2. Which type of interferometer is used in optical and infrared domains?
   - ☐ additive
   - ☐ multiplicative
   - ☐ a mixture of additive and multiplicative
3. How does an radio interferometer behave?
   - ☐ as low-pass plus bandpass filter
   - ☐ as a bandpass filter
   - ☐ as low-pass plus high-pass filter
4. A star located 10pc away from the Sun has an absolute visual magnitude M_V=5. The star is now placed in a galaxy that has a distance modulus DM=20. What is its apparent magnitude?
   - ☐ V=22.5
   - ☐ V=25
   - ☐ V=27.5
   - ☐ V=30
5. We consider two stars. Star 1, noted S1, has colors index B-V=-0.30 and V-R=-0.13. Star 2 has B-V=+0.58 and V-R=0.50.
   - ☐ S1 is hotter than S2
   - ☐ S1 is cooler than S2
6. We note m and M the apparent and absolute magnitudes, and d_{pc} the distance in pc.
   - ☐ M = m-5+5$\log_{10}(d_{pc})$
   - ☐ M = m+5-5$\log_{10}(d_{pc})$
   - ☐ M = m-5-5$\log_{10}(d_{pc})$
7. We consider two stars. S1 is a $2M_\odot$ star with M_V=+4 and a bolometric correction BC_1=-0.16. S2 is a $10M_\odot$ star. Both stars are on their main sequence phase and we assume that the Mass-Luminosity relation is $L \propto M\hat{}\alpha$, α=3.5. The bolometric magnitude of S2 is:
   - ☐ M_2 = +2.28
   - ☐ M_2 = -2.28
   - ☐ M_2 = -1.96
   - ☐ M_2 = +9.96
8. If p_{mas} is the parallax in mas, then the distance modulus is:
   - ☐ DM = 20 - 5$\log_{10}(p_{mas})$
   - ☐ DM = 10 - 5$\log_{10}(p_{mas})$
   - ☐ DM =-10 + 5$\log_{10}(p_{mas})$
   - ☐ DM =-15 + 5$\log_{10}(p_{mas})$
9. We note the mean-square fluctuations of the photon number is $(\Delta <n_\nu>)^2$. Photon noise dominates over thermal noise:
   - ☐ at low frequency, and $(\Delta <n_\nu>)^2 = <n_\nu>$
   - ☐ at low frequency, and $(\Delta <n_\nu>)^2 = <n_\nu>^2$
   - ☐ at high frequency, and $(\Delta <n_\nu>)^2 = <n_\nu>$
   - ☐ at high frequency, and $(\Delta <n_\nu>)^2 = <n_\nu>^2$
10. A radiotelescope of diameter D=12m is used to map a molecular cloud located a 150pc at a frequency ν=115 GHz. In order to avoid aliasing of spatial frequencies, the spatial sampling θ_s must satisfy:
    - ☐ θ_s > 22.4"
    - ☐ θ_s < 22.4"
    - ☐ θ_s > 44.8"
    - ☐ θ_s < 44.8"
11. A CCD has been designed using Si semi-conductor dopped with Sb. The gap energy is E_{gap}=39meV. The domain of wavelength that can be measured is:

- ☐ $\lambda < 64\mu\mathrm{m}$
- ☐ $\lambda < 32\mu\mathrm{m}$
- ☐ $\lambda > 32\mu\mathrm{m}$
- ☐ $\lambda > 64\mu\mathrm{m}$

2 Exercise 1 (/6 pts)

A protoplanetary disk located at 60 pc has a radius of 200 au. It is observed with a single dish radiotelescope of diameter D=12m the CN(3-2) rotational line at a frequency ν=340 GHz. The disk is seen exactly face-on and we neglect the Keplerian broadening. We also assume that the turbulent broadening is negligible.

1. What is the antenna power pattern P of a single-dish antenna in terms of the aperture function A. Give the definition of the beam-solid angle Ω_A. What is the relation between the effective area A_e and beam solid angle Ω_A for a radio telescope?
2. What is the angular resolution in au?
3. What is the beam dilution factor?
4. A line is detected with an intensity T_{mb}=1K. What is the emitted intensity of the line?
5. If the kinetic temperature is 30K, what is the expected linewidth? What spectral resolution, in kHz, is required to resolve the line (at least three spectral channel per FWHM).
6. The central protostar has a mass $M=1M_\odot$. We want to resolve the orbit of an Earth-like planet. What would be the baseline B of an interferometer if observing at $\lambda=1\mu\mathrm{m}$, and λ=0.8mm.
7. We use the ALMA radio-interferometer with a baseline of 10km to observe the 3-2 line of CN at 340GHz. Each antenna has a diameter of 12m. What is the field of view? IF we note P the power pattern of a single antenna, and D the dirty beam, what is the observed brightness in terms of the sky brightness I_{sky}?

3 Exercise 2 (/4 pts)

A diffuse interstellar cloud containing dust is observed with a bolometer.

1. We recall that the NEP is given by NEP=$(4kTG)^{1/2}/\eta$. What is the NEP and explain the different factors in this expression.
2. The dust has a temperature T_d=30K. Assuming that the dust radiates as a black-body, What is the wavelength λ_{peak} of the peak of the dust emissivity? At which wavelength should one observe to be in the Rayleigh-Jeans approximation?
3. The cloud was observed with the IRAS and Herschel satellites at λ=100 and $500\mu\mathrm{m}$. Compute the measured brightness at these wavelengths. Put the result in MJy/sr.
4. At $500\mu\mathrm{m}$, the NEP is 5.3E-17 W $Hz^{-1/2}$, and the aperture efficiency is 0.70. The Herschel primary mirror has a diameter of 3.5m. Recalling that the NEFD=2NEP/(A_{eff} $\Delta\nu$) with A_{eff} the effective area and $\Delta\nu$ the bandwidth, compute the NEFD of the Herschel/SPIRE at $500\mu\mathrm{m}$.
5. Give the expression of the signal-to-noise ratio (S/N) in terms of the NEP, the source power P_s, and the integration time Δt. The same relation applies for the NEFD.
6. From this relation, compute the source intensity in mJy that can be measured with S/N=5 in 1 hr.