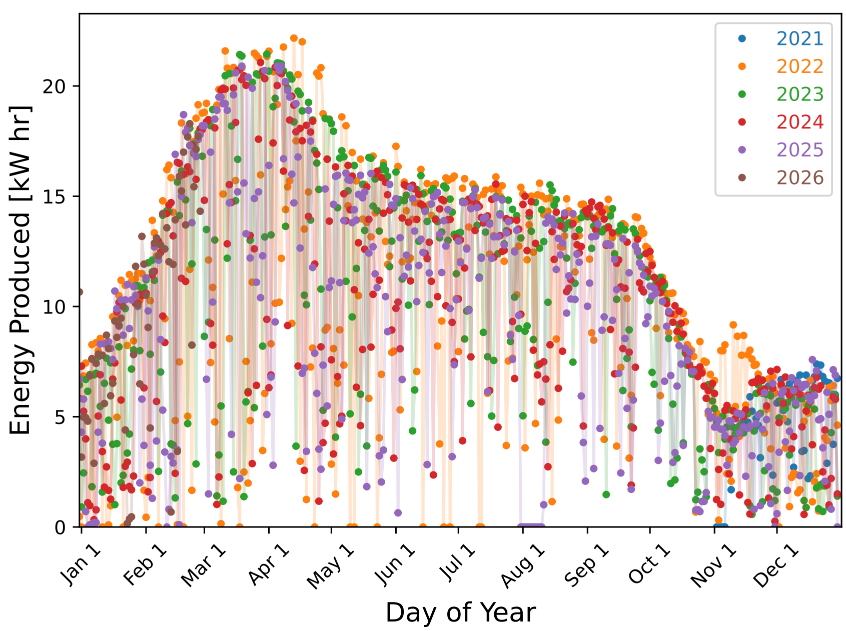
UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Physical Astronomy (ASTR 391) — Prof. Crossfield — Spring 2026

Problem Set 6
Due: Friday, Apr 3, 2026, 9am Kansas Time
This problem set is worth **42 points**.

As always, be sure to: show your work, circle your final answer, and use the appropriate number of significant figures.

1. **Solar Energy [16 pts]**

Figure 1 below shows the daily energy produced by Prof. Crossfield's rooftop solar panels over the past few years.



(a) Describe the general trends you observe in this plot. [4 pts]

Solution: The production is very repeatable from year to year: a peak in early Spring (when the sun is relatively high, but leaves aren't out); a long plateau through the summer (when the sun is high, but partly blocked by trees), a steep drop in the fall (when the sun is lower, and leaves are still up), and a slight rebound in winter (when the leaves are finally gone).

Lots of occasional, intermittent dips down to lower production, resulting from cloudy/snow-covered days.

(b) Calculate the Solar Constant, the typical flux of sunlight incident on the Earth, in W/m^2. [3 pts]

Solution: Since $F = L/(4\pi d^2)$, we simply calculate

$$F_{SC} = \frac{L_\odot}{4\pi(1\ \mathrm{AU})^2} \approx \boxed{1400\ \mathrm{W\ m^{-2}}}. \quad (1)$$

(c) Prof. Crossfield's solar panel system has a total collecting area of roughly 20 m^2. Estimate the maximum power (in W) that you might expect the panels to produce. [2 pts]

Solution: In the absolute best case, we might assume a power production of

$$P = F_{SC} \times (\text{area}) \approx (1400 \text{ W m}^{-2})(20 \text{ m}^{-2}) \approx \boxed{30,000 \text{ W}}. \quad (2)$$

But the world not being a perfect place, it's probably significantly less than that.

(d) Using your estimate of the maximum power, estimate the total energy (in kW-hr, killowatt-hours) that might be produced in a day. [3 pts]

Solution: Since $P = E/t$ and we might have 10 good hours of production per day, we just have

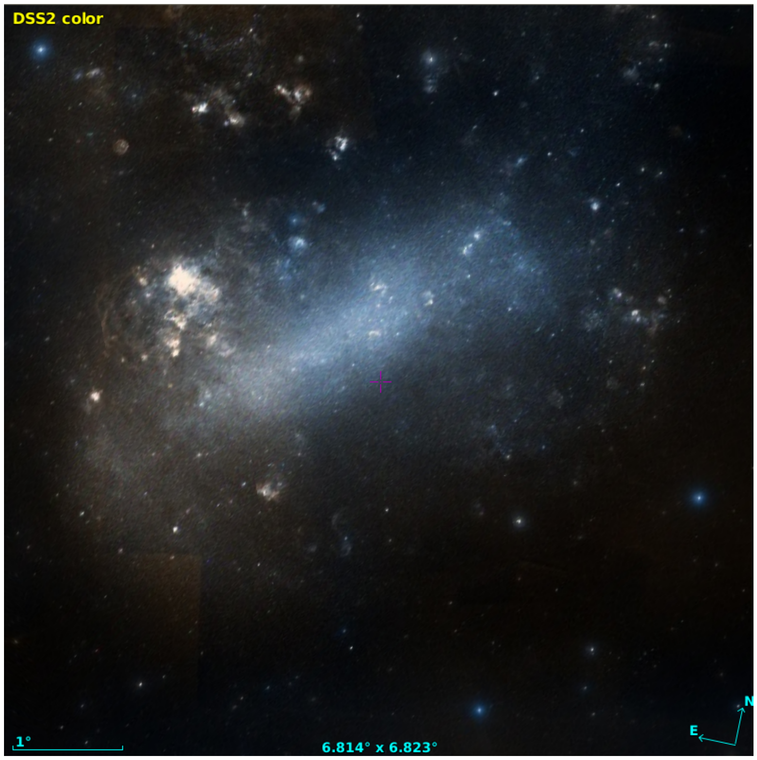
$$E \approx (30,000 \text{ W})(10 \text{ hr}) \approx \boxed{300 \text{ kWhr}}. \quad (3)$$

(e) In fact, the system never produces more than about 5 kW of power at peak, and rarely more than ∼20 kw-hr of energy per day, at maximum. Describe why these numbers are significantly lower than your rough estimates. [4 pts]

Solution: The atmosphere absorbs some sunlight before it can reach the Earth's surface. The solar panels only convert light at some wavelengths into electricity; some energy goes unused. Even at the usable wavelengths, panels are not 100% efficient. The panels do not always point straight at the sun, so their *effective* cross-sectional area is usually $<20\,\text{m}^2$.

2. **A Galaxy (not so) Far, Far Away [26 pts]**

The Large Magellanic Cloud (LMC) is a dwarf/irregular galaxy fairly near to the Milky Way. Here is its selfie, in Figure 2:



(a) The total apparent brightness of the LMC at visible wavelengths is a visual magnitude of ∼0.1, corresponding to roughly 10^8 photons/sec/m^2/nm. Assume that all these photons are visible-wavelength, and then estimate the observed flux density, F_λ, from the LMC in W/m^2/nm. [5 pts]

Solution: We need to convert from a photon rate (in photons/second) into an energy rate, or power (J/s, or just W). We can do this because we know each photon has an energy

$$E_\gamma = h\nu = \frac{hc}{\lambda}. \tag{4}$$

At visible wavelengths, $\lambda \approx 500$ nm. So we have

$$F_\lambda \approx \left(10^8 \text{ photons/sec/m2/nm}\right) \times \frac{hc}{500 \text{ nm}} \approx \boxed{4 \times 10^{-11} \text{ W m}^{-2} \text{ nm}^{-1}}. \tag{5}$$

(b) Assume further that all energy from the LMC is radiated at visible wavelengths, and then estimate the total flux observed from the LMC, in W/m^2. [4 pts]

Solution: To convert from flux density to flux, we assume all energy comes out in the visible, from roughly 300-700 nm — so, $\Delta\lambda \approx 400$ nm. Thus:

$$F \approx F_\lambda \Delta\lambda \approx \left(4 \times 10^{-11} \text{ W m}^{-2} \text{ nm}^{-1}\right)(400 \text{ nm}) \approx \boxed{1.6 \times 10^{-8} \text{ W m}^{-2}}. \tag{6}$$

(c) The parallax to the LMC is roughly 20 μas. Estimate the distance to the LMC, in pc. [2 pts]

Solution: By now, this is an easy one.

$$d = \frac{1''}{\theta_{par}} \text{ pc} = \frac{1}{20 \times 10^{-6}} \text{ pc} = \boxed{50 \text{ kpc}}. \tag{7}$$

In fact, such a tiny parallax angle is just about at the utter limit of what modern astronomy tools can measure.

(d) Use your value for the distance to estimate the total luminosity of the LMC, in both W and $L_\odot$. [4 pts]

Solution: Since again we know that $F = L/(4\pi d^2)$, we just estimate that

$$L_{LMC} \approx F \times \left(4\pi d^2\right) \approx \left(1.6 \times 10^{-8} \text{ W m}^{-2}\right)\left(3 \times 10^{43} \text{ m}^2\right) \approx \boxed{5 \times 10^{35} \text{ W} \approx 1.2 \times 10^9 L_\odot}. \tag{8}$$

We can check that this answer makes sense: we know (or can look up on Wikipedia) that the LMC is significantly smaller than the Milky Way. The Milky Way has $\sim 10^{11}$ stars, so it makes sense that the LMC should have a luminosity smaller than $10^{11} L_\odot$.

(e) Given the image of the LMC, estimate its angular diameter (in deg), physical diamer (in pc), and angular area (solid angle, in square degrees — $\square^o$). [6 pts]

Solution: It looks from the image that the dimensions of the LMC on the sky are roughly $3^o \times 8^o$, for an area on the sky of $\Omega \approx \boxed{2}4\square^o$. Let's split the difference and just say its angular diameter is $\theta \approx \boxed{5^o \approx 1/12 \text{ radian}}$.

Then its physical diameter D is just something like

$$D \approx d\theta \approx 50 \text{ kpc} \times \frac{1}{12} \approx \boxed{4 \text{ kpc}}. \tag{9}$$

(f) Use your estimate of the LMC's solid angle to estimate its average surface brightness, I_λ, in W/m^2/nm/$\square^o$. How does this compare to the value of $\sim 10^{-13}$ W/m^2/nm/$\square^o$ that we estimated for M31 (the Andromeda Galaxy) in class? [5 pts]

Solution: We would estimate this using something like

$$I_\lambda \approx \frac{F_\lambda}{\Omega} \approx \frac{4 \times 10^{-11} \text{ W m}^{-2} \text{ nm}^{-1}}{24\square^o} \approx \boxed{1.7 \times 10^{-12} \text{ W/m2/nm/}\square^o}. \tag{10}$$

... which is at least within a factor of ten or so of what we got in class.